University of Oslo

Effect of a structured and concerted approach to improve endodontic diagnostics and treatment in public dental clinics

A PhD thesis by Kristin Jordal

The studies were conducted at the *Department of Endodontics, Institute of Clinical Dentistry, Faculty of Dentistry, the University of Oslo* in collaboration with *Møre and Romsdal Public dental Service* and with funding from the *Centre for Oral Health Services and Research, TkMidt, Trondheim.*

Kristin Jordal
Institute of Clinical Dentistry, Faculty of Dentistry
University of Oslo
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Supervisors

Hovedveileder: Pia Titterud Sunde

Medveiledere: Dag Ørstavik, Rasa Skudutyte-Rysstad, Abhijit Sen, Tone Fagerhaug

Institutt: Department of Endodontics, Faculty of Dentistry, University of Oslo, Oslo, Norway

Finansiering: Center for Oral Health Services and Research, TkMidt, Trondheim, Norway

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[signature removed]

Ålesund,

List of Publications

Paper I Jordal K, Valen A, Ørstavik D. Periapical status of root-filled teeth in Norwegian children and adolescents. Acta Odontol Scand. 2014 Nov;72(8):801-5. doi: 10.3109/00016357.2014.913193. PMID: 24931925.

Paper II Jordal K, Sen A, Skudutyte-Rysstad R, Ørstavik D, Sunde PT. Effects of an individualised training course in endodontics on the knowledge and insights of dentists in Public Dental Service in Norway. Acta Odontol Scand. 2021 Aug;79(6):426-435. doi: 10.1080/00016357.2021.1876915. PMID: 33503389.

Paper III Jordal K, Skudutyte-Rysstad R, Sen A, Torgersen G, Ørstavik D, Sunde PT. Effects of an individualized training course on technical quality and periapical status of teeth treated endodontically by dentists in the Public Dental Service in Norway: An observational intervention study. Int Endod J. 2022 Mar;55(3):240-251. doi: 10.1111/iej.13669. PMID: 34817881.

Abbreviations

AAP	acute apical periodontitis
AP	apical periodontitis
CAP	chronic apical periodontitis
CBCT	Cone Beam Computed Tomography
CDE	dental CE
CE	continuing education
CI	confidence interval
COS	core outcome set
EBP	evidence-based practice
ESE	the European Society of Endodontology
GDP	general dental practitioner
NiTi	Nickel titanium
NSD	Norwegian Centre for Research Data
PAI	the periapical index
PAIend	PAI score at the last follow-up radiograph
RCT	root canal treatment
PDS	public dental service
Q1	pre-intervention questionnaire survey
Q2	post-intervention questionnaire survey
REC	regional ethic committee
Ref Group	postgraduate candidates in other dental speciality programs
Spec Group	specialists
Test Group	GDPs in DPS, Møre & Romsdal
UiO	University of Oslo

1. Introduction

Although endodontic treatment makes up only a few per cent of the total performed dental treatment (1), about half of all adults possess a root filling (2-4). At dental educational institutions and in specialist practice, a success rate for endodontic treatment above 90% is shown in teeth without preoperative apical periodontitis (AP) and 75-85% in teeth with preoperative AP (5-10). On the other hand, systematic reviews and metanalyses of cross-sectional studies on endodontic treatment in the general population in various countries (11, 12) indicate the prevalence of AP in root-filled teeth to be approximately 40%. In a repeated cross-sectional survey among 35-year-olds in Oslo, Norway, the prevalence of AP in root-filled teeth increased from 18% in 1973, 26% in 1984, 38% in 1993 to 43% in 2003 (13-16). And in a recent survey, the prevalence of AP in root-filled teeth among 65-year-olds in Oslo was 35% (17).

In Norway, dental services are divided into a public and private sector (18). Dental treatment provided by the public dental service (PDS) is free for patients 0-18 years of age, mentally disabled adults and elderly living in an institution or receiving home nursing care. Most adults receive dental care from private general dental practitioners, mainly financed by patient charges. Most specialists work in private practice, and these are mostly situated in the largest cities. Access to specialists is, therefore, very variable.

We need to gain more knowledge of the outcome of root canal treatments in PDS in Norway and of the potential positive effect of a mandatory CE course in endodontics for dentists.

1.1 Pathogenesis of apical periodontitis

Microbial infections from carious lesions are considered to be the most common cause of endodontic treatment (19). Dental caries, tooth fractures, dentin preparation, marginal leakage, or root resorption may directly or indirectly expose the pulp to microorganisms via dentinal tubules and induce pulpitis, i.e., inflammation of the dental pulp. Untreated pulpitis will lead to pulp necrosis, and eventually, the pulp and root canal system will become infected. Without a functioning blood flow, the bacteria can multiply in the necrotic pulp out of reach from the host immune system. Bacteria and their products induce both specific and nonspecific immune responses in the periapical area. Periapical bone loss is the main indicator of apical periodontitis and can only be detected in radiographs (20-25). Apical periodontitis can be chronic (CAP) or acute apical periodontitis (AAP). CAP is most common and represents a 'balance' between the bacteria in the root canal and the host response. Usually, patients are unaware of any symptoms associated with these lesions, which are often

only noted as incidental findings during a routine radiographic examination. When the 'balance' is disturbed, an acute inflammatory reaction may develop, often with severe symptoms (26).

1.2 Implications of apical periodontitis

A systematic review and metanalysis of epidemiological studies, reporting the prevalence of AP, providing data from 639 357 teeth has shown that AP may be found in 52% (95% CI 42%-56%) of the adult population worldwide (12).

Apical periodontitis may have several negative implications:

- With time, biofilm in the root canal gets more treatment resistant. Thus, the longer the tooth is left untreated, the greater the risk of endodontic treatment failure and sequels to the infection (27, 28).
- An acute apical abscess is usually localized to oral tissues, but in some cases the infection may spread and result in severe complications or even mortality (sinusitis, brain abscess, airway obstruction, Ludwig's angina, cavernous sinus thrombosis, bacterial osteomyelitis, necrotizing fasciitis) (29-36).
- The anatomic closeness of the microflora of the root canal to the bloodstream can cause bacteraemia with possible systemic consequences (37). Bacterial adherence to endocardial surfaces may promote infective endocarditis.
- Most of the published studies on associations between CAP and increased incidence of cardiovascular disease events found a positive association (38-40), but the quality of the existing evidence is moderate, and a causal relationship cannot be established.
- Prematurity and low birth weight were associated with radiographically detected CAP (41).
- A literature review found that a poorer periapical status correlates with poor glycaemic control in type 2 diabetic patients (42)
- Apical periodontitis has been described as the direct cause of paraesthesia of the mandibular or mental nerve (43).

1.3 Endodontic treatment

The purpose of endodontic treatment is either to prevent the development of apical periodontitis or to establish conditions for its healing by infection control and elimination of bacteria from the root canal (44). Pulpectomy, the removal of the pulp tissue, is performed in teeth with vital pulps. The pulp is only considered to be superficially infected, and it is crucial not to add any bacteria during the treatment. In nonvital cases with cultivable microorganisms, antisepsis in thorough chemo mechanical preparation of the root canals is

the key to an optimal result (45-51). The root filling has the aim of sealing the canal space to prevent reinfection of the canal and to isolate any remaining bacteria from their food source (52-55) *(Fig. 1)*.

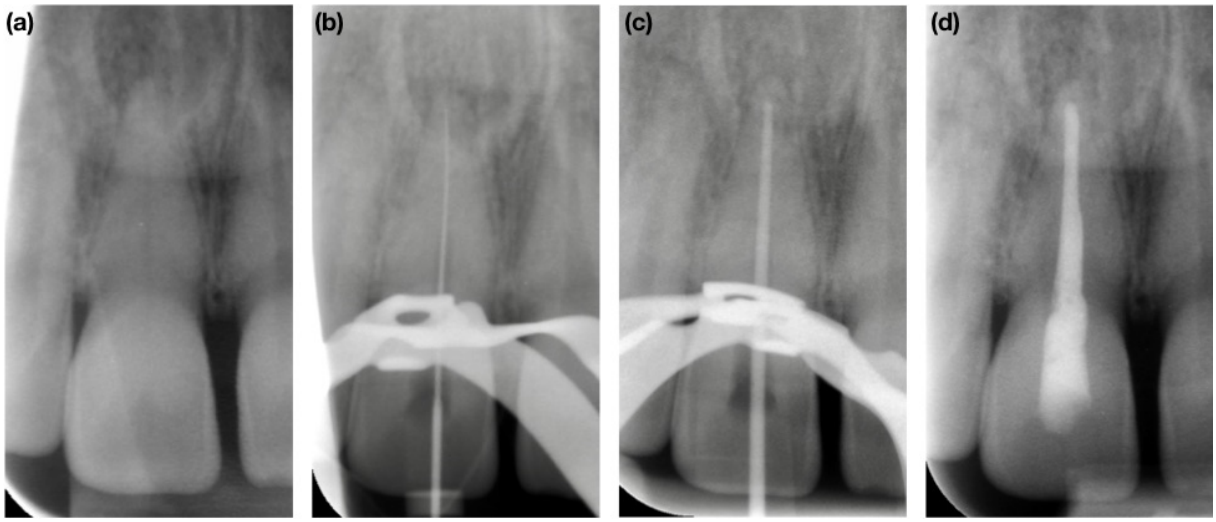

Figure 1. Steps in endodontic treatment, tooth 11: Preoperative radiograph (a), working length radiograph (b), master cone radiograph (c), finishing radiograph (d). [Radiographs from the radiographic study material in Møre & Romsdal.]

The endodontic prognosis has been shown to be significantly better in cases with no cultivable micro-organisms at the time of root filling compared with cases in which bacteria are still detectable (56, 57). A high level of asepsis in the use of rubber dams and sterile instruments is decisive. Lack of rubber-dam use has been associated with a significantly reduced survival rate of root-filled teeth (58, 59). Several studies (60-66) show that endodontic treatments in general dental practice are not always being performed by the same standard as recommended by the European Society of Endodontology (ESE) quality guidelines (67). This applies especially to the use of rubber dams and may indicate some dentists' lack of knowledge of the factors affecting the prognosis. The dentist's attitude towards asepsis is of crucial importance during treatment, but it is seldom reflected in written records and of course cannot be seen in postoperative radiographs.
There is no evidence regarding the importance of type of files used for preparations for the treatment outcome. Pettiette et al. found better prognosis with NiTi over steel hand files, but several studies showed that rotary or reciprocating files do not appear to have any further improvement on the treatment outcome (8, 68-70).

1.4 Endodontic outcome measures

Outcome is a clinical measure used to make judgments about the efficacy and effectiveness of treatment (71). A successful endodontic outcome is defined by both clinical and radiological features (72, 73), measured in terms of reduction or absence of a periapical lesion, absence of pain, resolution of clinical signs such as swelling or sinus-tracts, or tooth survival. Impact on the quality of life, resource use, and adverse events are other measures that could be included (74). Although some outcome studies use radiographic assessment of periapical healing combined with these clinical features (5-9, 75), there is variability and a lack of consensus in describing outcomes in endodontic research (76). Systematic reviews demonstrate that outcome studies have limitations due to a lack of standardization (77). Recently, much emphasis is made on creating a standardized set of outcomes that should be included in all trials and outcome studies, a "core outcome set" (COS) (78-83).

The two core imaging modalities for radiographic detection and monitoring of apical periodontitis are periapical radiographs and Cone Beam Computed Tomography (CBCT). CBCT was developed in the late 1990s to produce 3-dimensional scans of the maxilla-facial skeleton at a considerably lower radiation dose than conventional computed tomography (84). It gives a more accurate interpretation of the anatomy, and several studies prove that although the specificity of both periapical radiograph and CBCT are high, the sensitivity is better with CBCT. (85, 86). Despite CBCT superiority (87), the current recommendations are not yet in favour of its systematic use (AAE and AAOMR joint position statement 2015), because of the "as low as reasonably achievable" (ALARA) principle. Therefore, periapical radiograph remains the x-ray of choice, especially for epidemiological studies. A study by Kruse et al. indicates that the diagnostic accuracy parameters in CBCT may be lower for root-filled roots (88). Hence the diagnosis of AP on root-filled roots using CBCT may be less accurate than for non-root-filled teeth. Panoramic radiographs have limitations in the detection of AP lesions due to low sensitivity and the possibility of false-negative diagnosis. Nevertheless, several cross-sectional studies have used panoramic radiographs (89, 90).

1.4.1 Periapical healing

The most common methods of assessing periapical health radiographically are by the method according to Strindberg's criteria (91) and by the periapical index, PAI (92) *(Fig. 2)*.

Strindberg judges the success of root filled teeth based on absence of radiological signs of infection, such as normal contours and width of the periodontal ligament and intact lamina dura. Failure is based on discontinuous or poorly defined lamina dura and or a visible periradicular rarefaction.

PAI was introduced for unbiased radiological appraisal of root-filled teeth with standardized calibration of observers (92). PAI relies on the comparison of the evaluated radiographs with a set of five reference images, which represent histologically confirmed periapical conditions

(93). By reducing bias associated with the interpretation of radiographs, this method permits reproducible comparisons among different studies.

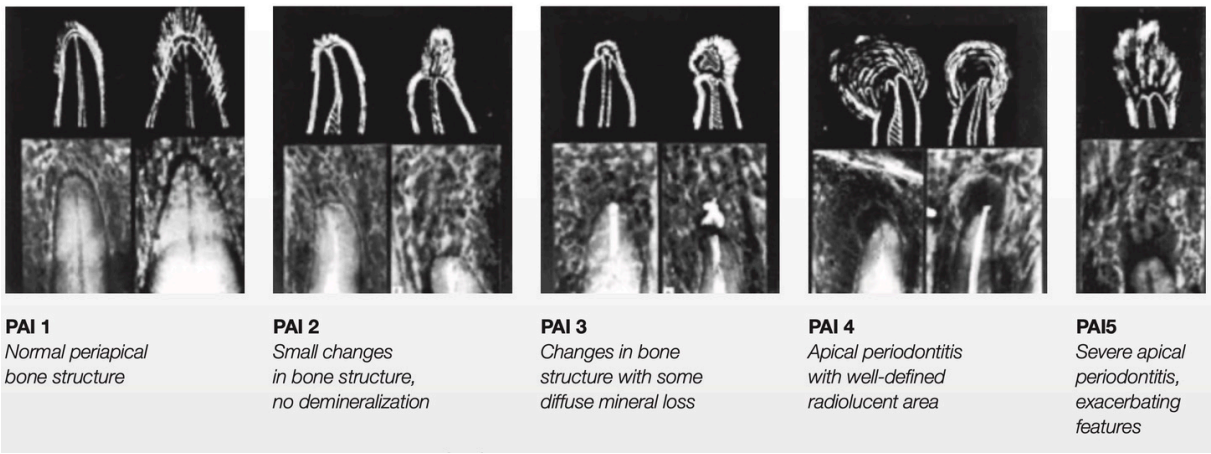

Figure 2. Periapical Index. Periapical radiographs and illustrations of the five PAI scores. [Reproduced with permission from (92)].

The periapical index (PAI):

Periapical status

- Healthy teeth:
  - PAI 1 or 2
- Diseased teeth:
  - PAI 3, 4 or 5

Treatment outcome

- Success:
  - PAI 1 or 2 at follow-up
- Failure:
  - PAI 3, 4 or 5 at follow-up

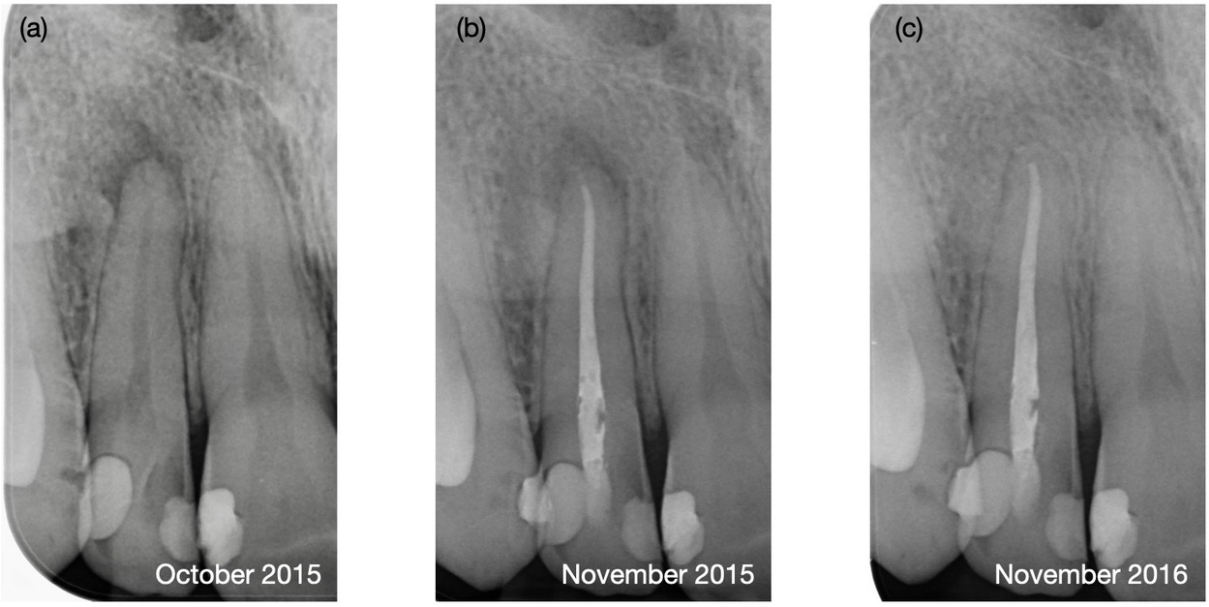

Figure 3. Healing of apical periodontitis. (a) Tooth 12 presenting preoperative apical periodontitis, PAI4. (b) Immediate postoperative radiograph of tooth 12, PAI4. (c) Follow-up radiograph of tooth 12 one year after treatment demonstrates resolution of the apical periodontitis, PAI1. [Radiographs from the Møre & Romsdal study material.]

In outcome studies, the follow-up period for determination of success should be long enough to capture the conclusion of the healing process in most of the study samples. While complete healing may take longer, controls after one year are considered adequate for detecting changes indicative of the final outcome (94, 95) *(Fig. 3)*.

1.4.2 Technical quality of root filling

Root canal treatment is a technically demanding field of dentistry, and a favourable outcome of endodontic treatment is dependent on the technical quality of the root filling (96-98). This concept is confirmed clinically: the quality of endodontic treatment, as judged by the appearance of the root filling in radiographs, is strongly correlated to treatment outcome (6, 7, 60, 91, 99-102). Technical root filling quality is most often evaluated radiologically by its density and length (96, 103), but also in some cases by taper and transportation (104, 105). It is well known that endodontic treatment requires good technical skills. Nevertheless, according to the study by Dahlström et al 2017, many general dental practitioners reported that root canal treatment was often performed with an overall sense of lack of control (106).

1.5 Continuing education courses in dentistry

Much effort is used to develop an evidence-based approach to healthcare. The discrepancy between best practice from research evidence and dental treatment routines in clinical practice is referred to as 'the science-practice gap' (107). The effectiveness of different

strategies for the implementation of research findings have been systematically reviewed (108-110). Didactic educational meetings and the issuance of guidelines were found to have little or no effect. Effective interventions, on the other side, were outreach visits, reminders, and interventions that included two or more of the following: audit and feedback, reminders, local consensus processes, or marketing, and workshops (108, 110).

Continuing dental education courses are routinely assessed by questionnaires completed by the participants (111-113), and it is assumed that favourable feedback is an indication of a beneficial effect of the course. However, there is limited information on the effects of continuous education courses on the actual performance of treatment providers and treatment outcome assessed in patients. Objective criteria for change and improvement in participants' knowledge and clinical performance are most often applied in tests immediately after completion of the course (114, 115), and lasting clinical performance is not usually tested. In endodontics, some have actually managed to change and improve dentists' clinical routines and the technical quality of the root fillings through pedagogical interventions (104, 105, 116, 117) but without a corresponding improvement in the treatment outcome (103).

2. Aims

2.1 Hypothesis

The null-hypothesis was that a CE course in endodontics would not improve knowledge, technical quality, or treatment outcome of root canal treatments among general dental practitioners (GDPs) in Møre and Romsdal PDS.

2.2 General objectives

There is limited information about the outcome of endodontic treatment in PDS and also scarce information on the effect of CE courses in endodontics. Therefore, the overall aim of the present thesis was to provide new knowledge of endodontic treatment quality and outcome among dentists in PDS, and to assess if a structured educational course could improve the quality of endodontic diagnostics, treatment quality, and treatment outcome.

2.3 Specific objectives

- To investigate periapical status of root-filled teeth in 9–17-year-olds in the county Møre and Romsdal in western Norway by searching for indications, results, and amount of endodontic treatment and associations of treatment outcome with clinical and demographic variables (Paper I).

- To evaluate the knowledge and insights of dentists in Møre and Romsdal county, Norway, towards endodontic diagnostics and treatment principles before and after attending a continuing education (CE) course (Paper II).

- To evaluate the effect of a CE course on technical quality and periapical status of root-filled permanent teeth in Møre and Romsdal county, Norway (Paper III).

3. Methodological Considerations

3.1 Study populations

To assess the knowledge and outcome of root fillings performed by public general practitioners, we enlisted all general dental practitioners (GDP) employed in Møre and Romsdal PDS. The PDS in the county consisted in 2014 of 67 dentists. In paper I and III, we evaluated the technical quality and outcome of root filled teeth. The selection of teeth was done in the PDS electronic dental record system. Inclusion criteria for teeth were endodontic treatment in permanent teeth, performed by GDPs, with more than 1-year follow-up and radiographs interpretable for PAI scoring. In paper I the selection was further limited to children and adolescent patients born in 1994–2001. To evaluate the effect of a CE course, we investigated in paper III teeth treated by the participating dentists, before and after the course. We could have used a control group of dentists who did not implement the course, such as in the study by Koch et al. 2009 (117), on assessment of the effect of an educational intervention among general dental practitioners in a intervention county and a control county. An advantage of using the same dentists in two following periods of time is to avoid bias from regional differences. The disadvantages are possible changes over time and the risk of selection bias.

In paper II we measured dentists' knowledge and insight and used the dentists as their own controls. This method has also been used in similar studies (104). The GDP group response was compared with a “Gold Standard”. The “Gold Standard” was members of the Norwegian Society of Endodontology. The endodontists were considered a valid and relevant source of up-to-date knowledge and insight. Specialists are supposed to provide optimal clinical services to the public, and one may consequently assume that this is based on the optimal use of theoretical and practical knowledge. These are referred to as the Spec Group. A reference group (Ref Group) was also created to compare the GDPs in Møre & Romsdal with GDPs from other parts of Norway. The Ref Group consisted of postgraduate candidates in dental speciality programs other than endodontics. The specialist candidates were chosen because we assumed that this group was representative of general practitioners in Norway. Dentists admitted to specialist education are relatively recent graduates who should have up-to-date knowledge and insight, but also have had some exposure to clinical practice and attitudes prevalent in non-academic, non-specialist environments.

3.2 Intervention

The intervention was in the form of an educational training program conducted in 2014, aiming at imparting knowledge on the influence of prognostic factors, contemporary endodontic routines, and an engine-driven, reciprocating file technique in the PDS. Efforts

were made to prepare and plan the CE course to be of the best possible benefit to the participants.
The course was based on the pedagogic principle that most efficient learning will take place through interactive sessions, which enhance participant activity (108, 116, 118-121). A purely theoretical course, only with lectures, was therefore not an issue. All dentists attended two one-day courses with a total of 12 theory lectures, two video demonstrations, 4 sessions with hands-on training (255min), 2 sessions of quiz, and 7 short sessions of information exchange and completion of questionnaires, discussions, questions, and evaluation (110 min). These two days were separated by a period of 5 months for self-training, and all participants performed endodontic treatment on at least two teeth with the reciprocating technique.
No other intervention studies on the same topic have previously been performed in Norway. Some courses have been performed in Sweden (103, 105, 116, 117, 122), but they have a different organization of dental services. It was, therefore, difficult to know what kind of course should be performed that could have an effect.

3.3 Sample size

To ensure reliable results, it is important to have an appropriate sample size when conducting trials. We had no knowledge of the frequency of endodontic treatment in the PDS of Møre & Romsdal or of the follow-up rate of these root-filled teeth and no a priori opportunity to assess the sample size. Instead of trying to calculate a sample size, we therefore included all treated teeth for a period in Møre & Romsdal. This county was chosen because it does not have good referral opportunities to dental specialists and is, therefore, more representative than counties with large cities, such as Oslo and Bergen, which have dental education and good access to specialists.
In paper I, we chose to study root canals performed before October 24, 2011, by the Public Dental Services (PDS) in Møre & Romsdal County on all individuals born in 1994–2001. Inclusion criteria were: endodontic treatment on a permanent tooth, treatment performed by a general practitioner, follow-up time more than 1 year and radiographs interpretable for PAI scoring. This resulted in a sample of 1182 teeth that had some kind of endodontic treatment in which 174 teeth in 155 patients fulfilled the inclusion criteria (*Fig. 4*).
In paper III, we knew from paper I that many teeth were root filled, but that follow-up was far from favourable. A large number of teeth had treatment initiated but not completed, due to extractions, treatments not completed within the time limit, or patients being referred to a specialist. The dentists did not have established guidelines on follow-ups, and the recall rate for follow-up of endodontically treated teeth was low *(Fig. 5)*.
Therefore, in paper III, a reminder to the dentists was included in the dental records of patients who had received root canal treatments to ensure follow-up radiographs were taken

of the relevant teeth when patients attended the clinic for the annual recall. Five hundred and one teeth were treated in the pre-course period, and 544 teeth post-course. Post-operative and follow-up periapical radiographs were available for 45% pre-course and 41% post-course. A large number of radiographs were excluded due to unsatisfactory quality. Several patients had reached the age of 22 and were no longer entitled to public dental treatment, including any obligation to attend a recall session.

3.4 Data collection

3.4.1 Root canal treatments (Papers I and III)

Endodontic treatments by general practitioners in Møre and Romsdal PDS were identified in the county's electronic dental record system (EDR). The data collected consisted of chart entries and radiographs of root-filled teeth.

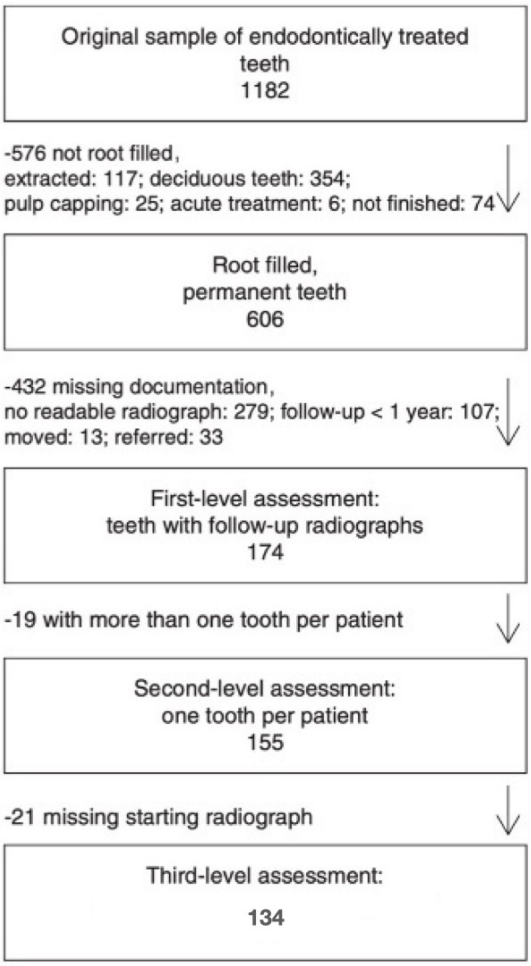

Figure 4. Flow chart for tooth inclusion in Paper I.

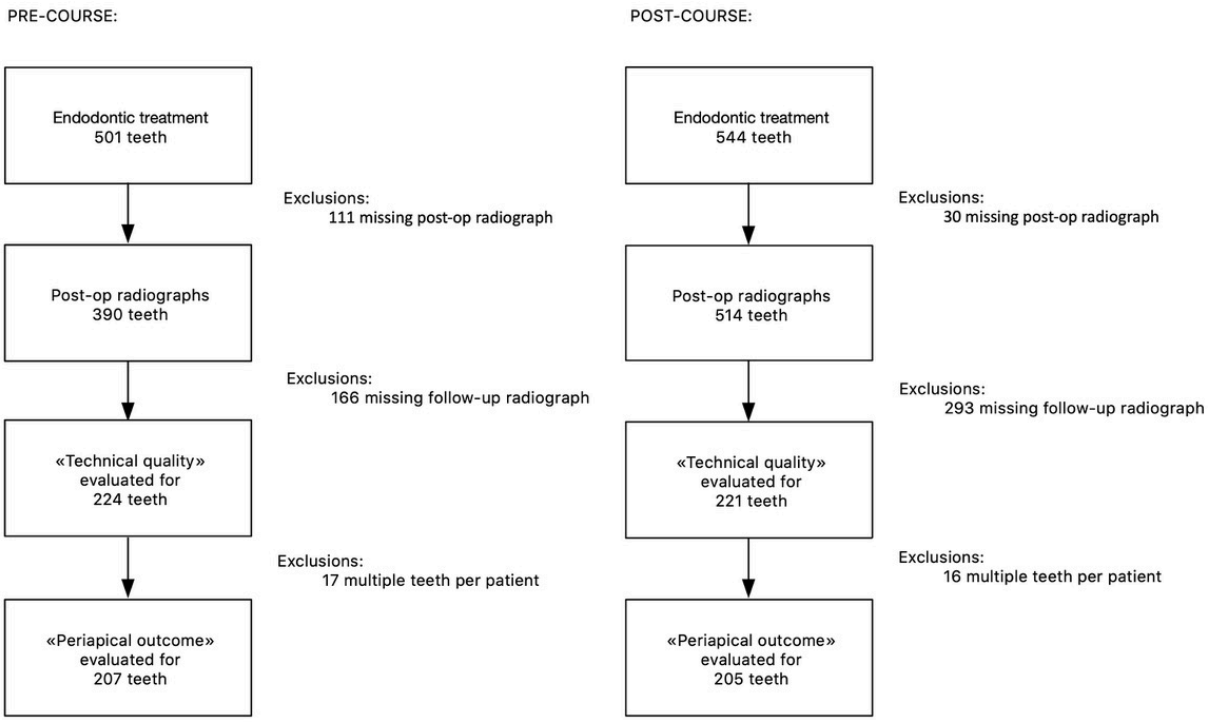

Figure 5. Flowchart of tooth inclusion and exclusion for teeth treated pre- and post-course, Paper III.

All the patient records were reviewed manually. We found shortcomings in the dental record registrations, such as missing or obvious errors in registration of the preoperative diagnoses, such as no apparent association between clinical diagnosis and radiographic periodontal status. Therefore, the diagnoses were based on evaluation of radiographs and radiographic scores rather than written diagnoses from the dental records.

3.4.2 Questionnaires (Paper II)

All study participants answered a background questionnaire (Appendix I) that aimed to collect information related to the participating dentists´ work experience and treatment procedures. It was important for us to know how the participating dentists currently treated their patients in terms of planning the CE course's content. The background questionnaire would also allow the assessment of differences in knowledge and the effect of learning among subgroups of dentists.

Prior to attending the course, a main questionnaire, which assessed knowledge and insight related to factors perceived to influence the prognosis of endodontic treatment before, during, and after treatment, was sent to the participants (Nettskjema®, University of Oslo) (Appendix II). After finishing the course, the main survey was answered a second time. The surveys were originally asked in Norwegian and then translated into English before statistical

analysis. The survey was also presented to specialist candidates in other disciplines at the Faculty of Dentistry and to Norwegian endodontists. To enable to compare the results in Møre and Romsdal with other studies, the questions and procedure were copied from Bjørndal et al. (123) excluding the last three items in their questionnaire (infected root canal, bad smell, and antibiotic use).

3.5 Data analyses

3.5.1 Periapical outcome (I, III)

In paper I, each radiograph was coded independently and assigned a PAI score by one examiner. The operator was blinded to whether the radiographs were taken immediately postoperatively or at follow-up. The examiner was calibrated against 100 reference radiographs until an observer agreement with a kappa value >0.61 was reached. By using the PAI index, direct and valid comparison with other clinical and epidemiological studies was facilitated. For any given tooth, the immediate-post-operative radiograph and the last follow-up were scored. PAI scores at follow-up radiographs (PAIend) were dichotomized, with PAIend 1 and 2 scored as normal periapical status (success) and PAIend 3, 4, and 5 as apical periodontitis (failure). If the follow-up was at only 1 year and the PAI score had moved from 4 or 5 to 3, it would be included as success.

In paper III, each radiograph was coded independently and assigned a PAI score by two examiners. The operators were in addition to being blinded to whether the radiographs were taken immediately postoperatively or at follow-up, blinded to whether they were in the pre-course or post-course group and thus avoided bias. The examiners were calibrated like in paper I. The two operators independently examined and scored all radiographs. The weighted kappa value for interobserver agreement of PAI scores was 0.86. In cases of one PAI score value difference, the higher score was chosen. The two observers agreed in 70% of all observations and in 98% whether the tooth was healthy (defined as PAI score 1 or 2) or not. In 14 of 251 cases of disagreement, the difference was of two or more PAI score values. These images were reviewed again, and a final consensus was reached after a discussion with a third evaluator. Only root canal treatments undertaken by dentists employed both before and after the intervention were included. There was significantly longer follow-up for teeth in the pre-course group, with an average of 30 months, in contrast to 21 months post-course. Strict and loose criteria were used for the evaluation of periapical health. The periapical outcome 'healthy' was defined as all teeth with PAI 1 or 2 at follow-up (strict criterium), and the outcome: 'healing' was defined as all teeth with PAI 1 or 2 at follow-up plus teeth with PAI 4 or 5 at the start, which scored PAI 3 at follow-up (loose criterium). The cause of the

change in method from paper I was to enable comparison of the results to other studies. In the studies by Burns et al. 2022 (10) and Ng et al. 2007 (75), similar criteria were used. The term 'strict' was used on a complete resolution of the periapical lesion and 'loose' when the existing periapical lesion had a reduction in size.

3.5.2 Technical quality (I, III)

In paper I, a method for quality evaluation of root fillings was developed. Root filling quality was quantified on a 4-grade visual scale by one examiner (KJ), measuring the root filling density (*Fig.6*). The 4 categories were made to visualize 1: root filling with no visible voids, 2: root filling with small visible voids, 3: root filling with large voids, 4: very leaky root filling. In cases of multirooted teeth, each root was assessed separately, and the tooth was assigned the score of the worst root. Root filling quality scores 2–4 included smaller to larger voids and were pooled into a category of unsatisfactory quality vs score 1, which had no visible voids in the radiograph and was considered satisfactory. In this paper, there was no evaluation of root filling lengths. It can be discussed if the length of the root filling should have been included as this is decisive for the treatment outcome (6, 10).

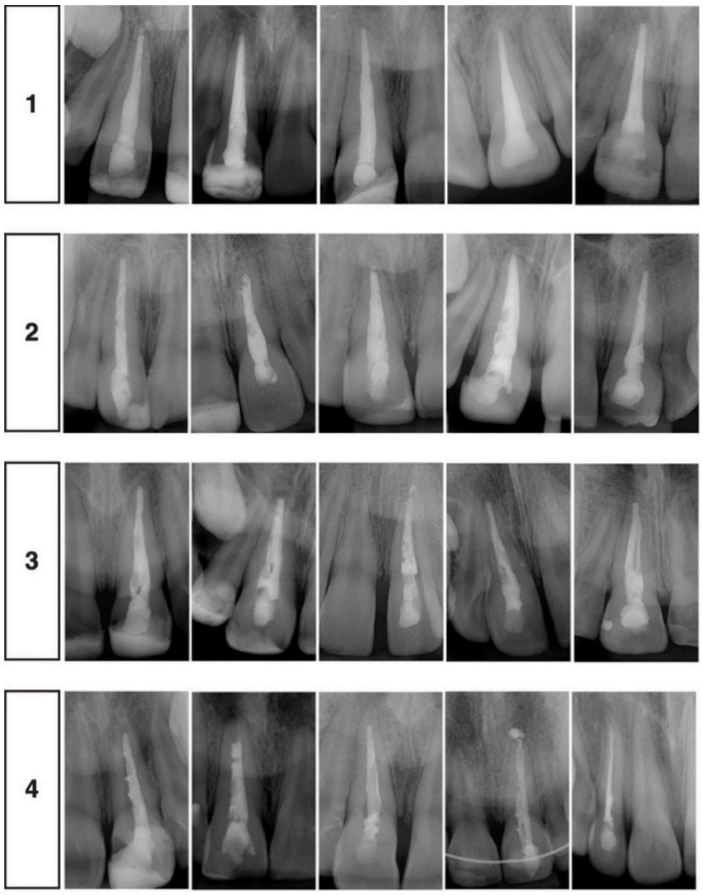

Figure 6. Scoring system for root filling quality, developed by the author (KJ) (paper I). The experimental radiograph is compared with those of the references and assigned the score of the reference which it resembles the most.

In paper III, root filling quality was evaluated in follow-up radiographs by one examiner (KJ) using the same scoring system for root filling density as in paper I, in addition to an extension of the image processing program ImageJ (124, 125). ImageJ was added to enable the saving of coordinates for calculations of root-filling length, bone height, and the root- or root-filling curvature. These parameters were considered important regarding technical quality and treatment outcome and comparison of the pre-course and post-course groups. The images were manually calibrated by film size. Specific points were marked in the X-ray, and the application stored the coordinates to facilitate further calculations (*Fig. 7*).

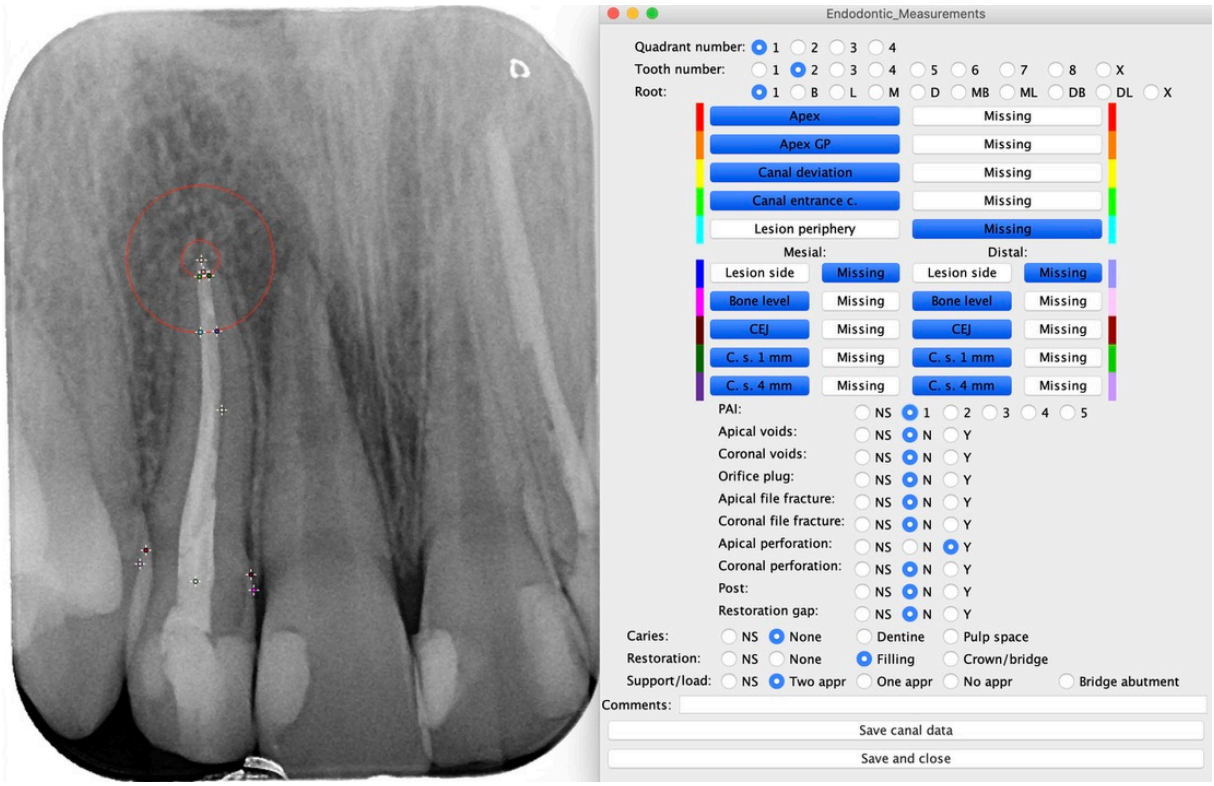

Figure 7. Screenshot of the ImageJ application interface which shows markings on the radiograph indicating coordinates for further calculations in addition to registration options for PAI, root filling density, etc.

Root filling density was recorded subjectively as either of good quality (score 1) or unsatisfactory quality (score 2-4). Overfilled root canals or fillings more than 2mm short of the radiographic root apex were considered unsatisfactory lengths. Root fillings ending at the apex (flush) to 2 mm from the apex were considered of adequate length, as in the study by

Koch et al 2015 (103), but slightly different from Molander et al. 2007 (105) and Dahlström et al 2015 (104) who used a limit of ≤2.5 mm from the apex, and from Kirkevang et al. 2000 (96) who used ≤3 mm. For statistical analysis, ≤2 mm was optimal for calculations with the data comparing the two groups of teeth in our study. Teeth with periapical extrusion of sealer were not considered overfilled. Both density and length had to be satisfactory for the root filling to be considered of adequate quality. In cases of multirooted teeth, each root was assessed separately, and the tooth was assigned the score of the worst root. We considered using the root as a unit as it gives a larger amount of data which in turn can provide stronger statistics. However, to enable comparisons between quality and periapical health, it was convenient to use the same parameters as in the evaluation of periapical health in which the outcome of a root would be dependent on the tooth.
The saved coordinates defining canal entry, canal deviation, and root apex were used to calculate the root angle (a modified Schneider angle) in the same root (125), which were labelled S angles and categorized into <25 and >=25 degrees for no or slight versus marked curvature, respectively.

3.5.3 Analysis on the effect of the CE course on knowledge and insights (II), treatment outcome and root filling quality (III)

Forty-nine of 67 dentists (73%) completed the CE course and answered the questionnaires which were used for evaluation of knowledge and insights in paper II.
To assess the effect of the CE course on knowledge and insight, the main survey was answered twice, as a pre- (Q1) and post (Q2) intervention questionnaire survey. We compared the response after the course (Q2) with the previous one (Q1). Any change in replies would be interpreted as learning. The dentists were compared to specialist candidates in other disciplines at the Faculty of Dentistry, to evaluate if their knowledge were comparable to other GDPs in Norway. The participants were also compared to the Norwegian community of formally trained endodontists.
The effect of the CE course on treatment outcome and root filling quality was measured by comparing the proportions of healed and healing teeth as well as root filling quality before and after the dentists had attended the course.

3.6 Statistical analyses

3.6.1 Statistical analyses Paper I

In paper I, Pearson's chi-square test analyses were performed on associations of periapical outcome with technical quality and other registered variables.

3.6.2 Statistical analyses Paper II

In paper II, the data was analysed using SPSS version 26 software (SPSS, Chicago, IL, USA), and Python software was used to plot figures. Continuous and categorical variables were presented as mean (standard deviation) and frequency (percentage), respectively. The data was not normally distributed, and therefore non-parametric tests were performed. Wilcoxon Sign test and Mann–Whitey U test was used on paired and unpaired data, respectively. The significance level was set at $p < .05$. Endodontic prognostic factors were ranked according to their perceived significance. Mean scores with corresponding 95% confidence interval (CI) for pre-, per- and post-operative prognostic factors are presented in snake plots. Heatmaps were used to highlight results obtained with the questionnaires to assess the effects of the training course and similarities or differences between the participating dentists, the Spec Group, and the Ref Group.

3.6.3 Statistical analyses Paper III

In paper III, descriptive statistics analyses and mixed-effect logistic regression analyses were performed to evaluate the effect of the CE-course. Inter-group comparisons between categorical variables were assessed using Pearson's chi-squared test. The present comparison is of performance (quality and outcome) by one group of clinicians before and after the course. Statistical comparisons were used to test the 0 hypotheses.
The significance level was set at $p < .05$ in all studies.

The low follow-up of root-fillings may be a source of selection bias. In cases of incomplete treatments or cases referred to specialists, the treatments may have been more difficult than the average case. Patients experiencing symptoms from treated teeth may be more prone to attend to recall-sessions. None of the included cases was follow-up radiographs from acute treatments. It has been proven difficult to conduct studies outside universities with high recall rates (60, 126-129). Rates comparable to university studies are not to be expected. Nevertheless, it could have been reasonable, in our study, to invite all the relevant patients for a control radiograph and not expect this to be done at the annual appointments.

3.7 Ethical considerations

The project has been presented to the (REC South-East Norway) without objections (ref no. 2015/265 B) and has been approved by the Norwegian Centre for Research Data, NSD (Ref no 39991). Because the attending dentists adopted a standard, nonexperimental treatment protocol and knowledge about health or disease per se is not the purpose of this study, this project thus falls outside the provisions of the Health Research Act, cf. section 4 of the Health Research Act and does not require local review board approval according to the European

Guidelines for Good Clinical Practice (CPMP/ICH/135/95). The confidentiality and anonymity of patients and course participants were maintained in accordance with national and regional (Office of the Møre and Romsdal Public Dental Health Service) requirements. The papers were written in accordance with “Strengthening the reporting of observational studies (STROBE)” recommendations (130).

4. Summary of the Results

This dissertation is based on the results from three studies on the quality and outcome of endodontic treatment in Møre and Romsdal PDS and the effect of an outreach training program. The studies were conducted at the *Department of Endodontics, Institute of Clinical Dentistry, Faculty of Dentistry, the University of Oslo* in collaboration with *PDS in Møre and Romsdal County* and with funding from the *Centre for Oral Health Services and Research, TkMidt, Trondheim.*

4.1 Paper I

In paper I, the periapical status and technical quality of root-filled permanent teeth of 9–17-year-olds in Møre & Romsdal county, Norway was evaluated. Among the 155 root-filled teeth in 9–17-year-olds included in the study, 38% of the root fillings were scored of the best quality (score 1), by presenting no voids in periapical radiographies. Forty-one percent scored 2, 16% scored 3, and 5% of the root fillings had a quality score of 4. Sixty-eight percent of treated teeth were upper front teeth, 11% were premolars, and 21% were molars.
The overall 'success rate' at follow-up was 75% when success was defined as PAI1 or PAI2 at follow-up. Molars healed less frequently than front and premolar teeth, but no significant impact was found on treatment outcome for patient age at treatment or if trauma was the cause of the treatment. Only 52% of the teeth with pre-operative apical periodontitis had healed. In this group of teeth with pre-operative apical periodontitis, significantly fewer healed in males than among females. Good root-filling quality was significantly correlated with good periapical status at the final follow-up. Many teeth without apical pathology at the initiation of treatment developed apical periodontitis after treatment and this led to periapical health not improving for the group of teeth.

4.2 Paper II

In paper II, the effect of a CE course in endodontics was evaluated in terms of change in knowledge and insight among the attending dentists. Two identical surveys were answered, before and after the course and judged by the ranking of endodontic prognostic factors. Forty-nine dentists completed the course and answered both questionnaires (*Fig. 1*). Seventy-one percent of the dentists were female, 45% had graduated less than 10 years ago, and 59% were educated in Norway. Most clinicians performed endodontic treatment less than once a week, and 22% reported that 'it may take months between each time'. Nearly half of the participants considered endodontic treatment to be difficult or very difficult.

Dentists in PDS differed significantly from specialists in their responses. The results were similar to previous results from Denmark (123).
After training, there was only moderate change in the dentists´ responses. The lack of change in the response of the Test Group before- and after the course was especially evident for the preoperative prognostic factors focusing mainly on diagnostic factors. Some responses changed to become even more divergent from the specialists after the course.
When the participating dentists attended the course, their responses were comparable to the responses of specialist candidates at the University of Oslo.
There were some minor differences in the knowledge before and after the course among the Test Group in relation to gender, years in practice, place of education, and use of rubber dam.

4.3 Paper III

In paper III, the effect of the CE course was evaluated in terms of technical quality and periapical outcome of root fillings performed by the attending dentists in Møre & Romsdal county.
Two hundred and twenty-four teeth were analysed before the CE course and 221 teeth after the course. The follow-up time ranged from 12 to 60 months. The proportion of teeth with adequate root-filling quality decreased from 48% pre-education to 35% post-education. The proportion of teeth with adequate root filling length *per se* was reduced significantly from 59% to 47%, mainly because short root fillings increased from 24% to 40%. The results on technical quality remained significant after adjusting for dentists' gender, years of experience and education place.
No significant improvement was observed in success rates pre- and post-course. For teeth with pre-operative apical periodontitis, however, there was a significant reduction in the proportion of root-filled teeth scored as 'healthy' after the course (56% versus 39%).
Analyses of all root-filled teeth (pre- and post-course) in relation to background characteristics of dentists indicated that teeth treated by female dentists had more often adequate root-filling quality and good periapical health at follow-up, and teeth treated by dentists educated in Norway and dentist who claimed to always use rubber dam were more often scored as healthy at follow-up. Further, the sensitivity analyses using less strict definition for periapical outcome revealed that the results did not vary from the main analyses.

5 Discussion

The main aim of this thesis was to evaluate and improve knowledge and skills in endodontic therapy as well as improve technical quality of root fillings and periapical health by introducing a CE course to PDS dentists in Møre and Romsdal county, Norway. The prevalence of apical periodontitis on root-filled teeth treated by dentists in Møre and Romsdal county was high. In our first paper the prevalence of apical periodontitis at follow up was 25 %, and in the third paper it was 29%. After introducing a CE course, we found a moderate improvement in dentists' knowledge and insight, but this was not reflected in the root filling quality and outcome. The prevalence of apical periodontitis at follow-up of was then 38%.

5.1 Periapical health (I, III)

In paper I, we found apical periodontitis on follow-up radiographs in 25% of all root-filled teeth, and persistent apical periodontitis in up to half of the teeth with pre-operative apical periodontitis. In comparison, other clinical studies (131-134) found respectively 64%, 29%, 52%, and 33% post-treatment apical periodontitis.

Most clinical studies on endodontic outcomes study the healing of treated teeth. If the time for interception was at the initiation of treatment, an even lower success rate should be expected due to several teeth being extracted before completion. In a study by Wigsten et al. 2021 (135) among patients at public dental clinics in Sweden , 35% of molar teeth had been extracted before treatment completion. The outcome of the above-mentioned clinical studies is in line with what is found in several cross-sectional studies on periapical health (13, 17, 136-147). Cross-sectional studies do not provide information on the incidence or healing of apical periodontitis. It provides information on the prevalence of the disease rather than the success/failure of treatment.

In paper I, it is a conundrum that there is no improvement in the average PAI score (1.7) of the included teeth ("all teeth") after receiving endodontic treatment (*Fig. 8*). Apical lesions that develop after root canal treatment may be seen in connection with poor asepsis and contamination during the endodontic treatment or secondary infection along a leaky root filling.

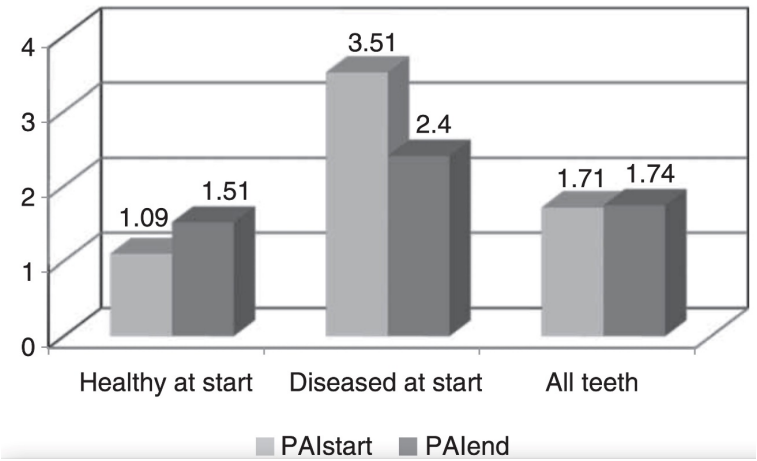

Figure 8: Average PAI scores from start to final control for sub-groups of teeth defined as healthy (PAIstart 1 or 2, n=92) or diseased (PAIstart 3, 4 or 5, n=42) at start and for the total material (n=134) (148).

Forty eight percent of the 174 teeth examined in paper I had one year follow-up. Large lesions will need more than a year to show radiographic healing. A recent systematic review of outcomes of root canal therapy (10), showed that studies with a minimum of four year follow-up period years had a better success rate. Another study nevertheless shows that the results after one year will give a good indication of healing, where 88% of the healed cases were detectable at 1 year (95). Caries or leakage may contribute to secondary AP developing later than 1 year after treatment and may form an argument of not using a prolonged follow-up time.

In paper III, we assessed the outcome of root canal treatments before and after introduction to a CE course. We included permanent teeth regardless of the patient's age. The results were similar to what was found in paper I. We found apical periodontitis in follow-up radiographs in 34% of all root-filled teeth and in 52% of the root-filled teeth with pre-operative apical periodontitis.
There was significantly longer follow-up for teeth in the pre-course group, with an average of 30 months, in contrast to 21 months post-course. Some teeth need more time to heal. Thus, a better outcome could be expected with longer follow-up (10, 75, 95). However, the multivariate analysis of the outcome in the data revealed that the length of follow-up had no significant impact on healing in our study. Ideally, a closer follow-up of the participants in between the course sessions, with clinic visits by the course holders, may have increased the effect of the course. However, with 36 urban and rural dental clinics involved, this approach was considered too resource intensive.

The number of root-filled teeth pre- and post-course varied at the individual dentist level. Some practitioners treated more teeth before the course, others more after, and there were large differences in the total number of teeth treated by the individual dentist. Dentists treating more teeth had a greater impact on the overall result. We wanted to study the course effect on the total number of root-filled teeth in Møre and Romsdal, not at the individual dentist level. These differences would reflect the everyday reality where some dentists treat or refer more teeth than others.

We decided to exclusively evaluate radiographs and thereby put the diagnoses based on radiographic scores rather than written diagnoses from the dental records. Thus, painful teeth without having a visible apical lesion in the follow-up radiograph potentially were scored as successful (selection bias) and give an inferior treatment outcome. In a study by Wigsten et al. 2021 (135), 50% of the patients reported current pain one to three years after completing a root canal treatment. Nevertheless, in paper III, this would be similar in the pre-course and the post-course groups and should not affect our findings.

A recent review and meta-analysis of the global prevalence of apical periodontitis included 114 cross-sectional, case-control, and cohort studies and revealed that 39% of root-filled teeth had visible AP (12). The prevalence of patients with AP in the Tibúrcio-Machado study was 52% and only slightly higher in developing countries (51%) than in developed ones (53%). Most studies included were cross-sectional studies. Cross-sectional studies will include newly treated teeth with apical periodontitis as “failures” because they have not yet healed radiographically, and these teeth thus affect the result negatively. Nevertheless, this proportion of "healing" teeth is unlikely to be enough to significantly affect the results. The proportion of root-filled teeth with apical lesions in the Tibúrcio-Machado study does not match the outcomes from studies we use as a basis for our treatment recommendations (6, 10, 101). These often-referred outcomes found in patient-based cohort studies are performed in specialist practice or at university clinics. In an updated systematic review of such outcome studies published between 2003 and 2020 by Burns et al (10) the pooled success rate of primary root canal therapy was estimated to be 82.0%. In a similar systematic review (75), which includes studies from 1922 to 2002, the pooled success rates were 74.7%. There is reason to believe that the root-fillings performed in university- or specialist clinics are performed according to a more thorough protocol and with stricter rules for aseptic technique and use of rubber dam than what the following studies indicate to be expected in general dental practice (149-151).

In Norway, most root fillings are performed by GDPs in general practises. Nevertheless, most cohort studies are patient-based and originate from student or specialist clinics where the teeth are treated by students or specialists with higher success rates than those reported in

population-based cohort studies on endodontic treatments performed in the general clinic (127-129).

We know that root canal treatments that were carried out in the past with the use of conventional NiTi hand files, rubber dams, and NaOCl and EDTA irrigation according to recommended guidelines (67, 152) had good results (5, 6, 9, 153). Many courses are being carried out on technical innovations like new machine-driven instrumentation to marginally improve the outcome of root canal treatment among specialists or dentists, more than average interested in root canal treatments. Possibly, more emphasis should be made where most root canal treatments are performed, to find which methods have the best effect to improve endodontic treatment outcomes in general practices. It is well known which prognostic factors have an effect on endodontic prognosis (6). Engine-driven endodontic NiTi instruments have been shown to provide root fillings of better technical quality than conventional hand files (103-105). But there is no evidence that the use of engine driven endodontic NiTi instruments provides an improved prognosis compared to hand instrumentation. Correct working length (5), irrigation (48), no overfilling (6), adequate root filling density, and the quality of the coronal restorations (96, 154, 155) are associated with improved outcome.

5.2 Technical quality of root fillings (I, III)

There is no current standardization of the quality scoring of root fillings, and it is, therefore, difficult to compare root filling qualities between studies.

It would be advantageous to have one generally accepted scoring system, a “core outcome set” (COS) on root filling quality, to compare studies more easily. A radiographic index of root filling density, such as the one we used in paper I and III, would prevent bias of individual perception between operators.

Several studies indicate that the quality of root canal fillings, in general, is inadequate (136, 143, 146, 156-158)

In paper I, on root-filled permanent teeth of 9–17-year-olds in Møre and Romsdal county, 42% of the root fillings were of adequate technical quality (density). In a Swedish study on adolescents and young adults (133), 49% of the root-filled teeth were adequately sealed. In a study by Clarke et al. (159), on treatments in permanent teeth among children in a UK teaching hospital, 61% of root canals were technically satisfactory.

In paper III, on technical root-filling quality of all age groups, we found that the total proportion of teeth with adequate root-filling quality (density + length) was 42%, (48% pre-course and 35% post-course. A CE course should have great potential for technical improvement. A Swedish qualitative study found that GDPs sometimes accepted poor root-filling quality because their competence limit had been reached (106). The authors expressed

thoughts suggesting that it might not be reasonable always to strive towards the optimal root filling quality in general dental practice. Prognostic deliberations were impeded by the seemingly paradoxical fact that very poor-quality root fillings were sometimes associated with apical healing, whilst good-quality root fillings were not, thus 'shortcuts' may gradually be introduced (106). It is known from other populations that the use of a rubber dam, although mandatory in academic training and fully adopted by endodontic specialists, may be largely abandoned in general practice (149).

5.3 Implication of the CE course (II, III)

A model for evaluating and analysing the results of educational, training and learning programs was published by Kirkpatrick in 1967 (160). It consists of four levels of evaluation: Reaction, Learning, Behaviour, and Results (*Fig. 9*). Each successive level of the model represents a more precise measure of the effectiveness of a training program. In our study, we measured the change in periapical health. This is level 4 in Kirkpatrick's model.

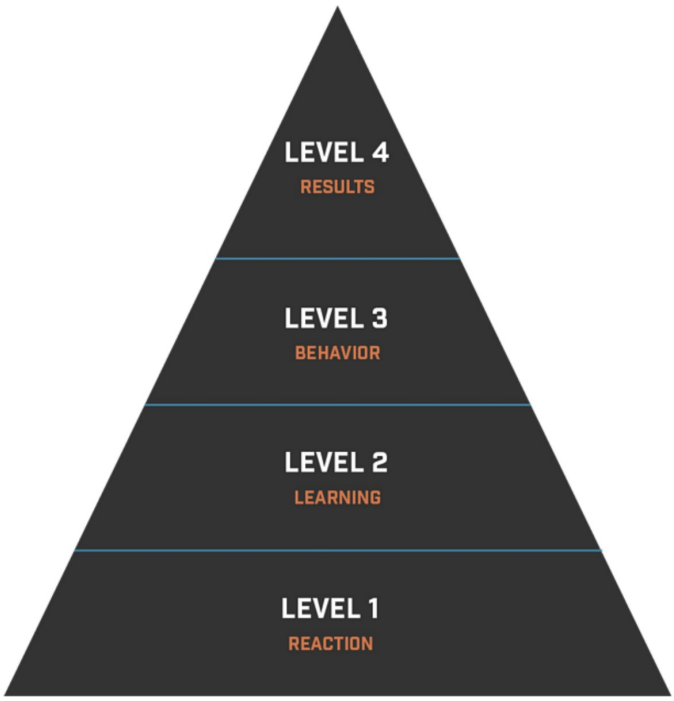

Figure 9: 4 Levels of the Kirkpatrick Evaluation Model

In an observational intervention study, the main aim is to attain a valid estimate of the effect of an intervention on the occurrence of a disease in the population (161). We therefore introduced the CE course. To the best of our knowledge, no other studies have studied the effect of dental CE courses in Norway beyond participants' self-evaluation.

In paper II, we studied the effect of the two-day continuing education course for general dental practitioners in the PDS of Møre and Romsdal, regarding knowledge of prognostic factors in root canal treatment, presented in a questionnaire. There were marked differences between the participants' responses ("Q1") and the response from the specialists. The results are comparable to those of (123) in Denmark (*Fig. 10*). In both studies, general practitioners tend to believe that the prognosis of endodontic treatment is more dependent on tooth-related factors than on operator-related factors.
We found only a moderate improvement towards the specialists' responses ("Spec Group") after the GDPs had completed the course ("Q2"). In our study, post-graduate candidates in other dental specialities at the Faculty of Dentistry, University of Oslo, also completed the questionnaire ("Ref Group"). The Test Group ("Q1" and "Q2") and the Ref Group answered quite similarly. When we put Bjørndal's and our findings into one figure, we see that the gold standards do not coincide. This shows that a gold standard may not always be a perfect gold standard. We still see that the tendency is the same and this is the main issue in this case.

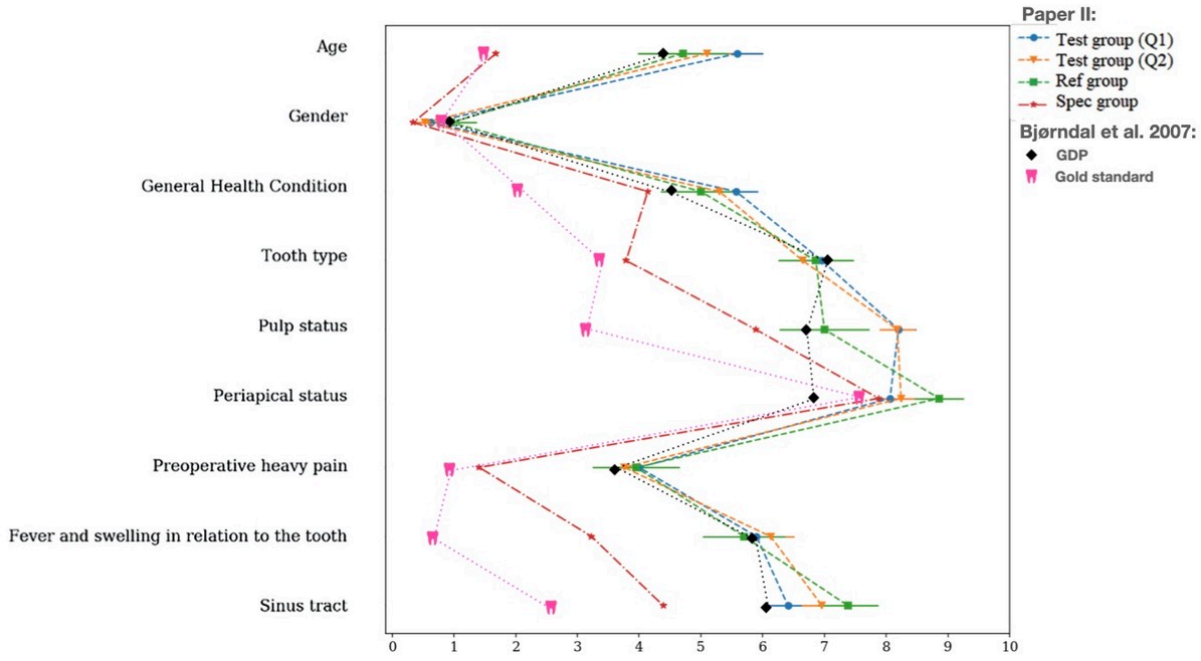

Figure 10: Snake plot of responses on preoperative factors perceived to influence endodontic treatment outcome by 1: our study (paper II) with Test Group (Q1 and Q2), the Ref Group and the Spec Group vs 2: the Bjørndal study with the gold standard (GS) compared with the general dental practitioners (GDP)

In paper III, we explored the clinical effect of the CE course. We compared teeth treated by the same dentists, before and after the course and found that the course did not improve

technical quality or treatment outcome. On the contrary, the course had a negative impact on quality caused by the increased proportion of short root-fillings. The highly significant increase in short root canal fillings from 24% pre-course to 40% post-course ($p < .001$) may be explained by the course emphasising poor outcomes in case of overfilling. When we adjusted for dentists' gender, dentists' years of experience and dentists' place of education, the decline in adequate quality remained significant ($p < .001$) and could not be due to these factors.

For practical reasons, the pre-course teeth had relatively longer follow-up than the post-course treated teeth with more than two years of follow-up in 60% vs. 37%. More molar teeth were treated post-course (40% vs. 31%), possibly because the dentists had (or at least believed they had) become more skilled and treated more difficult teeth in the post-course group. No other differences indicating increased difficulty of cases treated post-course were observed, as proportions of teeth with 'pre-operative apical periodontitis', 'retreatments', 'marked root curvature', and 'visible rubber-dam clamp on radiograph' in the pre- vs. post-course groups.

An alternative course format might have been considered. In the study by Dahlström et al. 2015 (104), dentists were educated by an endodontist to be coaches. The coaches were free to organize and conduct the training of the local GDPs. They had similar results as other Swedish studies with a combined lecture and hands-on course, showing an increased use of machine driven instrumentation and improved technical quality of root fillings (103, 105, 116, 117, 122), but with no improvement of periapical health (103).

In a systematic review of the effectiveness of continuing dental education by Firmstone et al. 2013 (162), five of the ten included studies used an outcome measure based on patient care, and only three of these did so independently using patient records rather than relying on dentists' self-report. Our participants self-evaluated the course to be of great value (data not shown). Nevertheless, it proved to have little or no effect on periapical health.

More studies are needed to evaluate CE interventions in dentistry. This is especially pressing given the large resources committed to supporting members of the dental team to participate in regular CE.

6 Conclusion

About one-fourth of all endodontically treated teeth and half of the endodontically treated teeth with pre-operative apical periodontitis treated in PDS in Møre and Romsdal had apical periodontitis.

A two-day continuing education course for the dentists in PDS did not substantially improve their level of knowledge, the technical quality of root fillings or the outcome of root canal treatments.

Based on our results, we conclude that continuing education of dentists is challenging, and more knowledge is needed on the implementation of new knowledge and quality assurance for established daily procedures among clinicians.

7 Future perspectives

The present study found that endodontic treatment outcome in Møre and Romsdal PDS was unsatisfactory, with a high prevalence of AP on root-filled teeth. Low-quality endodontic treatments seem to be a global challenge (11, 12), and highlight the importance of preventing endodontic treatment and focus on caries prevention in addition to proper treatment of deep caries. Laukkanen et al.(163) reported on the outcome of root canal treatment in general dental practice. They found that molars had the worst outcome compared to incisors and premolars both regarding technical quality of the root canal filling and healing of AP. These findings reflect the challenge dentists meet when performing technically difficult treatments, such as root canal treatment on molars.

A Swedish study (106) concludes that GDPs report high levels of stress and frustration in relation to RCT. RCT was often performed with "an overall sense of lack of control".

It might be unrealistic for a general dentist to master a wide spectre of dental treatments from complicated root canals to large prosthetic works. In addition to the challenges of mastering such a wide range of knowledge and skills, the dentist must also possess the necessary equipment. Few general practitioners are in possession of the same equipment that endodontists use, such as a microscope.

The treatment outcome was not improved by a 2 days-CE course in endodontics. Our studies as well as another Swedish study (103) indicate that continuing education programs and courses may have limited if any positive influence on the outcome of treatments provided by the participants. Thus, future evaluations of CE interventions in endodontics should use outcomes based on periapical health or tooth survival, as in the higher levels in Kirkpatrick's framework (160) to evaluate the health of patients and change in practice or behaviour as well as knowledge and understanding.

Looking at the relatively poor outcome of endodontic treatment in epidemiological studies worldwide in comparison to treatment performed in dental institutions (10, 12, 75), effort should be made to train undergraduate students to perform root canal treatments while they are students and receptive to information. One strategy might be to review and strengthen endodontology in the dental education curriculum. Training in endodontics for dental students is crucial for establishing good technical skills and treatment routines. The routines and techniques learned during undergraduate training today are not reinforced sufficiently to withstand the peer and patient pressures later in practice. Later in the career, after years of bad habits, it becomes challenging to change these routines. Today, the minimum requirement of root canal treatments at the Faculty of Dentistry, UiO, is only 9 teeth, including 3 molars, and the pressure to do away with volume (case nos.) requirements is

substantial. While achieving a level of competence is the end goal of instruction in any clinical program, one may question the wisdom in allowing a reduction, rather than supporting an extension, of undergraduate teaching in endodontics. Another option might be that specialised general dentists could be trained to treat molars and perform retreatments. The Swedish government's official investigations, "Utredningen om högspecialiserad vård, 2015 (164), suggested that specialised care could be developed to give better and more equal healthcare. It concluded that RCT in molar teeth may be regarded as highly specialised care and that one possible way for the future development of endodontic care is to educate and train enough specialists in endodontics so that most RCTs, at least in molars, are undertaken by specialists. A study by Wigsten (165) in 2022 found a successful outcome of molars was achieved in just over half the cases and concluded similarly. Despite the deregulation that came with the dental care reform in 1999, most specialist dentistry in Sweden is still carried out in the PDS (Folktandvården), whereas in Norway almost all specialist dentistry is carried out in private practice. Despite these differences, studies indicate that the endodontic outcomes are similar in Norway and Sweden (13, 127, 144).

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Appendix I

Background questionnaire

Outreach: Bakgrunnsskjema

Hva er din Outreach-kode (tre bokstaver)? Det er viktig at denne er riktig *

Kjønn *

- [ ] Mann
- [ ] Kvinne

Fødselsår (hele årstallet): *

Yrkesbakgrunn

Tannlegeeksamen år (hele årstallet): *

Utdanningssted *

- ○ Bergen
- ○ Oslo
- ○ Tromsø
- ○ Utlandet (spesifiser under)

Hvis utlandet, hvor (by, land)

Hvor mange år har du arbeidet i offentlig tannhelsetjeneste? *

Hvor mange år har du arbeidet i privat praksis? *

Etterutdannelse/kurs i endodonti

	Ja	Nei
Har du deltatt på teoretisk kurs i endodonti siste 5 år?	○	○
Har du deltatt på praktisk kurs i endodonti siste 5 år?	○	○

Om du har deltatt på kurs, spesifiser hvilket/hvilke

Arbeidsprofil:

	Ca 1 gang, eller mer, i en vanlig arbeidsuke	1-3 ganger i måneden	Det kan gå måneder mellom hver gang	Veldig sjelden
Hvor ofte rotfyller du? *	○	○	○	○

	Jeg benytter bare manuell teknikk	Jeg benytter i hovedsak maskinell teknikk	Jeg benytter både manuell og maskinell teknikk
Hva er din rotfyllingsteknikk? *	○	○	○

Om du benytter manuell teknikk, hvilke er den/de viktigste årsakene? Du kan klikke for flere muligheter.

	Ja	Nei
Jeg vil kunne kjenne "hvor jeg er" og det gjør jeg best med manuell teknikk	○	○
Jeg synes kvaliteten på rotfyllingene blir bra med manuell teknikk	○	○
Jeg har ikke hatt teoretisk kursing i maskinell instrumentering	○	○
Jeg har ikke hatt praktisk kursing i maskinell instrumentering	○	○
Jeg har hatt praktisk kursing i maskinell instrumentering men våger ikke prøve på pasient	○	○
Jeg er redd for å frakturere filer med maskinell teknikk	○	○
Mine kollegaer har frarådet meg maskinell instrumentering	○	○
Vi har ikke blitt enige om å ha utstyr til maskinell teknikk på klinikken	○	○
Jeg utfører så lite endodontisk behandling at jeg ikke ønsker å bytte teknikk	○	○
Andre årsaker (se neste felt)	○	○

Hvis andre årsaker, hvilken/hvilke?

Om du benytter maskinell teknikk, hvilke er den/de viktigste årsakene? Klikk ja bare på den/dem som passer

	Ja	Nei
Jeg var ikke fornøyd med instrumenteringsresultatet med min tidligere manuelle teknikk	○	○
Jeg synes det er mindre slitsomt å instrumentere maskinelt sammenlignet med manuell teknikk	○	○
Jeg synes det går raskere å rense maskinelt	○	○
Jeg trenger færre behandlingsøkter for å rense ferdig	○	○
Jeg synes det er enklere å rotfylle med maskinell teknikk	○	○
Jeg synes at kvaliteten på rotfyllingene blir bedre med maskinell teknikk	○	○
Jeg har arbeidet i lengre tid med maskinell teknikk	○	○
Jeg startet med maskinell instrumentering etter å ha vært på teoretisk kurs	○	○
Jeg startet med maskinell instrumentering etter å ha vært på praktisk kurs	○	○
Vi har blitt enige om å ha utstyr til maskinell teknikk på klinikken	○	○
Andre årsaker	○	○

Hvis andre årsaker, hvilken/hvilke?

Hvilket av de følgende tre påstandene stemmer best med dine behandlingsprosedyrer: *

- ○ Uansett om tannen er vital eller nekrotisk forsøker jeg oftest å instrumentere og fylle tannen i en og samme behandlingsseanse
- ○ Uansett om tannen er vital eller nekrotisk velger jeg oftest å instrumentere, legge innlegg og fylle tannen i en senere behandlingsseanse
- ○ Vitale tenner instrumenterer og rotfyller jeg oftest i en seanse, men nekrotiske tenner gir jeg et innlegg

Her følger noen påstander du skal ta stilling til. Kryss av for den ruten som samsvarer best med dine behandlingsprosedyrer.

	Alltid	Nesten alltid	Ofte	Sjelden	Nesten aldri	Aldri
Diskuterer du det forventede behandlingsresultatet med pasienten? *	○	○	○	○	○	○
Jeg tar et innledende apikalrøntgen (startrøntgen): *	○	○	○	○	○	○
Jeg anvender kofferdam: *	○	○	○	○	○	○
Jeg tar indikatorrøntgen: *	○	○	○	○	○	○
Jeg benytter apexlocator: *	○	○	○	○	○	○
Jeg tar sluttrøntgen: *	○	○	○	○	○	○

Hva er årsaken i de tilfellene du ikke diskuterer det forventede behandlingsresultatet med pasienten? Du kan markere flere svaralternativ.

- ○ Jeg er selv ikke sikker på hvilket behandlingsresultat jeg kan forvente meg
- ○ Jeg synes ikke det er viktig informasjon
- ○ Pasienten etterspør ikke den informasjonen
- ○ Andre grunner

Hvis andre grunner, hvilken/hvilke?

Hvilket av de følgende tre påstandene stemmer best med dine behandlingsprosedyrer: *

- ○ Uavhengig av antall kanaler instrumenterer jeg oftest ferdig i en seanse
- ○ Jeg trenger oftest flere behandlingsseanser for å rense ferdig enrotede tenner
- ○ Jeg trenger oftest flere behandlingsseanser for å rense ferdig flerrotede tenner

Jeg bruker følgende instrumenter (du kan krysse av for flere):

	Ja	Nei
Hedstrøms-filer	○	○
K-filer	○	○
Reamere	○	○
Protaper	○	○
BioRace	○	○
Sendoline	○	○
Reciproc	○	○
BT-Race	○	○
Annet (skriv i boksen under)	○	○

Hvis annet, hva da?

Jeg irrigerer med (du kan krysse av for flere):

	Ja	Nei
Dakins væske (bufret natriumhypokloritløsning)	○	○
Ubufret natriumhypokloritløsning	○	○

EDTA	○	○
Klorheksidin	○	○
Annet (skriv i neste felt)	○	○

Hvis annen irrigasjon, hvilket middel?

Som rotkanalsinnlegg benytter jeg (du kan krysse av for flere alternativer):

	Ja	Nei
Kalsiumhydroksid (laget på klinikk)	○	○
Calasept eller annen kommersiell Ca(OH)2	○	○
Intet innlegg	○	○
Annet (skriv ut i neste felt)	○	○

Hvis annet innlegg, hvilket middel?

Jeg rotfyller med (du kan trykke på flere):

	Ja	Nei
AHplus og guttaperka	○	○
Annen sealer og guttaperka	○	○
Resilon/RealSeal	○	○
Guttaperkapoints som har høyere konisitet/taper og er tilpasset for maskinell teknikk	○	○
Vanlig lateralkondensering	○	○
"Single-cone"-teknikk uten lateralkondensering	○	○
Varm guttaperka	○	○
Biokeramer (eks. Endosequence, TotalFill)	○	○
Annet (se neste felt)	○	○

Hvis annen rotfyllingsmetode, kan du beskrive?

Her følger fire påstander du skal ta stilling til. Du kan krysse av flere svaralternativ: *

- ☐ Jeg har rutiner for å kontrollere det kliniske og røntgenologiske resultatet etter rotfylling (Etter 1 år, 2 år eller andre tidsintervall)
- ☐ Jeg har ikke rutiner for å kontrollere det kliniske og røntgenologiske resultatet etter rotfylling (Etter 1 år, 2 år eller andre tidsintervall)
- ☐ Jeg kontrollerer om pasienten har symptomer fra rotfylte tenner
- ☐ Jeg kontrollerer rotfylte tenner dersom de skal ha kroneterapi

Kjenner du til om dere har retningslinjer for endodontisk behandling ved klinikken, enten fra DOT MR eller fra andre kilder? *

Skriv gjerne en kommentar om forhold ved din endodontipraksis som kan belyse din situasjon

Nettskjema v21.2

Appendix II

Main questionnaire

Outreach Referanse For Kurset

Spørreskjema om endodontisk praksis

Vær snill og besvar spørsmålene slik DU gjør det eller DU tenker deg det; IKKE slik du tror andre eller eksperter mener det bør være.

Outreach-kode (denne må være riktig) *

Hvor stor er din interesse for fagfeltet endodonti? *

- Svært liten
- Liten
- Middels
- Stor
- Meget stor

Hvor vanskelig synes du endodonti er? *

- Veldig lett
- Lett
- Middels
- Vanskelig
- Svært vanskelig

Hvilke tenner endobehandler du oftest? *

- Fronttenner
- Premolarer
- Molarer
- Det er omtrent like mange av alle tanntyper

Hvilken henvisningsmulighet til spesialist i endodonti har du? *

- Kan ikke henvise
- I samme by
- I samme kommune
- I samme fylke
- Ikke i samme fylke

Når henviser du for endodontisk behandling? Flere svar er mulig. *

- [ ] Alltid
- [ ] Meget bøyde kanaler
- [ ] Molarer
- [ ] Revisjonsbehandling
- [ ] Oblitererte kanaler
- [ ] Komplikasjoner (filfraktur, resorpsjoner, perforasjoner)
- [ ] Endodontisk kirurgi
- [ ] Aldri

Hvor ofte henviser du for endodontisk behandling? *

- Aldri
- Sjelden: kanskje en gang eller to i året
- Ofte: flere ganger i løpet av året
- Alltid

Ut fra en totalvurdering av dine interesser og preferanser, ønsker du deg flere eller færre endodontikasus? *

- Mange flere
- Noen flere
- Ingen flere; det er passe som det er
- Færre
- Helst ingen

Ut fra din erfaring i egen praksis, vil du si at behovet for endodonti er *

- Sterkt økende
- Noe økende
- Stabilt
- Noe avtagende
- Sterkt avtagende

Kliniske rutiner.

Hvor ofte finner du fire kanaler i første molar i overkjeven *

- Aldri
- under 30 %
- 30-75%
- over 75%

Hva bruker du som midlertidig toppfylling? *

- [ ] IRM
- [ ] ZOE
- [ ] Cavit G
- [ ] Annet

Hvordan legger du midlertidig toppfylling? *

- Ned i bunnen av kavum
- Propper ned i kanalene

Behandlingsprinsipper.

Hva er din standardbehandling ved akutt pulpitt? *

- Trepanerer (åpner til kronepulpa og fjerner den) og lar stå åpent til neste behandling
- Trepanerer og legger kun midlertidig fylling over
- Trepanerer og legger en eugenol-pellet med midlertidig fylling over
- Trepanerer og legger inn Ca(OH)2 med midlertidig fylling over

Standardbehandling ved rotfylling

	Rotfylles ferdig i en seanse hvis du har tid	To eller flere seanser med Ca(OH)2 innlegg i kanalen mellom seansene

Standardbehandling ved rotfylling av vital tann?	○	○
Standardbehandling ved rotfylling av en avital tann uten apikal oppklaring?	○	○
Standardbehandling ved rotfylling av en avital tann medapikal oppklaring?	○	○

Hva benytter du til å fjerne smearlaget? *

- ○ NaOCl
- ○ EDTA
- ○ Klorheksidin
- ○ Fysiologisk saltvann
- ○ Annet

Hvor ønsker du at rotfyllingen skal avsluttes? *

- ○ Med en liten puff av sealer overskudd
- ○ Jevnt med røntgenolgisk apeks
- ○ 0-1 mm kortere enn til røntgenologisk apeks
- ○ 1-2 mm kortere enn til røntgenologisk apeks
- ○ Mer enn 2 mm kortere enn røntgenologisk apeks

Hva forstår du med langtidsinnlegg med Ca(OH)2 *

- ○ Mer enn en uke
- ○ Minst tre uker
- ○ Minst tre måneder
- ○ Minst seks måneder

Bruker du langtids-innlegg med Ca(OH)2? *

- ○ Ja
- ○ Nei

Hvis ja på forrige spørsmål, når?

- ☐ Hvis det er fistel
- ☐ Hvis symptomer vedvarer etter korttids-innlegg
- ☐ Hvis tidligere rotbehandling ikke har gitt røntgenologisk tilheling
- ☐ Hvis kanalen ikke blir tørr
- ☐ Ved behandling av tenner med stor oppklaring

På de neste spørsmålene svarer du på en skala fra 0 (ingen betydning) til 10 (svært stor betydning)

Hvor mye tror du disse forholdene FØR behandlingen betyr for tannens prognose ved endobehandling?

	0	1	2	3	4	5	6	7	8	9	10
Alder	○	○	○	○	○	○	○	○	○	○	○
Kjønn	○	○	○	○	○	○	○	○	○	○	○
Generell helsetilstand	○	○	○	○	○	○	○	○	○	○	○
Tanntype	○	○	○	○	○	○	○	○	○	○	○
Pulpas status (vital/nekrotisk/rotfylt) (uten apikal lesjon)	○	○	○	○	○	○	○	○	○	○	○

Periapikalstatus (lesjon/ikke lesjon)	○	○	○	○	○	○	○	○	○	○	○
Preoperative sterk smerte	○	○	○	○	○	○	○	○	○	○	○
Feber og hevelse ved tannen	○	○	○	○	○	○	○	○	○	○	○
Fistel	○	○	○	○	○	○	○	○	○	○	○
Vond lukt fra kanalen	○	○	○	○	○	○	○	○	○	○	○
Pas har brukt antibiotika	○	○	○	○	○	○	○	○	○	○	○

Hvor mye tror du disse forholdene UNDER behandlingen betyr for tannens prognose?

	0	1	2	3	4	5	6	7	8	9	10
Arbeidslengden	○	○	○	○	○	○	○	○	○	○	○
Irrigasjon med flere seanser	○	○	○	○	○	○	○	○	○	○	○
Innlegg ved vitalkasus	○	○	○	○	○	○	○	○	○	○	○
Innlegg ved nekrotisk pulpa	○	○	○	○	○	○	○	○	○	○	○
Innlegg for tenner med apikal oppklaring	○	○	○	○	○	○	○	○	○	○	○
Persisterende oppklaring på rotfyllingstidspunktet	○	○	○	○	○	○	○	○	○	○	○

Hvor mye tror du disse forholdene ETTER behandlingen betyr for tannens prognose ved endobehandling?

	0	1	2	3	4	5	6	7	8	9	10
Avstanden til apeks fra rotfyllingens spiss	○	○	○	○	○	○	○	○	○	○	○
Overfylling med sealer	○	○	○	○	○	○	○	○	○	○	○
Overfylling med guttaperka aller annen point	○	○	○	○	○	○	○	○	○	○	○
Rotfyllingens tetthet/homogenitet i apikale 1/3	○	○	○	○	○	○	○	○	○	○	○
Rotfyllingens tetthet/homogenitet i koronale 2/3	○	○	○	○	○	○	○	○	○	○	○
En propp i kanalen mot pulpakavum	○	○	○	○	○	○	○	○	○	○	○
Toppfyllingens kvalitet	○	○	○	○	○	○	○	○	○	○	○
Bruk av tannen som endepilar i bro	○	○	○	○	○	○	○	○	○	○	○
Bruk av tannen som endepilar med ekstensjonsledd bak	○	○	○	○	○	○	○	○	○	○	○
Tannens posisjon i buen (dobbel eller enkel eller ingen approksimal kontakt)	○	○	○	○	○	○	○	○	○	○	○

Hva er mest sannsynlig pulpas tilstand ved disse diagnosene? (bare ett svar er mulig)

	Frisk	Obliterasjon i pulpa	Inflammasjon lokalt i pulpa	Generell inflammasjon i pulpa	Partiell nekrose	Total nekrose	Nekrose med infeksjon
Hypersensibelt dentin	○	○	○	○	○	○	○
Karies i emalje	○	○	○	○	○	○	○
Karies i dentin	○	○	○	○	○	○	○
Karies til pulpa	○	○	○	○	○	○	○

Kronisk pulpitt	○	○	○	○	○	○	○
Akutt pulpitt	○	○	○	○	○	○	○
Kronisk apikal periodontitt	○	○	○	○	○	○	○
Akutt apikal periodontitt	○	○	○	○	○	○	○
Apikal cyste	○	○	○	○	○	○	○

Hvilken diagnose tenker du først på når det er...(bare ett svar er mulig)

	Frisk pulpa	Hypersensibelt dentin	Kronisk pulpitt	Akutt pulpitt	Akutt apikal periodontitt	Kronisk apikal periodontitt	Apikal cyste	Apikal abscess	Ikke endodontisk diagnose (perio, annet)
Palpasjonsømhet	○	○	○	○	○	○	○	○	○
Vertikal perkusjonsømhet	○	○	○	○	○	○	○	○	○
Horisontal perkusjonsømhet	○	○	○	○	○	○	○	○	○
Tidlig respons på elektrisk pulpatester	○	○	○	○	○	○	○	○	○
Middels respons på elektrisk pulpatester	○	○	○	○	○	○	○	○	○
Sen respons på elektrisk pulpatester	○	○	○	○	○	○	○	○	○
Misfarget tann (ikke av fylling)	○	○	○	○	○	○	○	○	○
Hevelse i overgangsfolden	○	○	○	○	○	○	○	○	○

Nettskjema v21.2

Original papers

Paper I

Paper II

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Effects of an individualised training course in endodontics on the knowledge and insights of dentists in Public Dental Service in Norway

Kristin Jordal , Abhijit Sen , Rasa Skudutyte-Rysstad , Dag Ørstavik & Pia Titterud Sunde

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Paper III

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ORIGINAL SCIENTIFIC ARTICLE

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Effects of an individualized training course on technical quality and periapical status of teeth treated endodontically by dentists in the Public Dental Service in Norway: An observational intervention study

Kristin Jordal[1,2] | **Rasa Skudutyte-Rysstad**[3] | **Abhijit Sen**[2] | **Gerald Torgersen**[4] | **Dag Ørstavik**[1] | **Pia Titterud Sunde**[1]

[1]Department of Endodontics, Faculty of Dentistry, University of Oslo, Oslo, Norway

[2]Center for Oral Health Services and Research, TkMidt, Trondheim, Norway

[3]Department of Cariology and Gerodontology, Faculty of Dentistry, University of Oslo, Oslo, Norway

[4]IT Section, Faculty of Dentistry, University of Oslo, Oslo, Norway

Correspondence
Kristin Jordal, Department of Endodontics, Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Postboks 1142, Blindern, Oslo 0318, Norway.
Email: kristin_jordal@hotmail.com

Abstract

Aim: To investigate the effect of a continuing education course on technical quality and treatment outcome for root filled permanent teeth in Møre and Romsdal County, Norway.

Methodology: Fifty-two dentists employed in the Public Dental Service in Møre and Romsdal county, Norway, completed a two-day continuing education course in root canal treatment. Periapical radiographs of root filled teeth treated before and after the course, with at least one-year follow-up were identified and scored for technical quality and periapical status. Technical root filling quality was assessed by density and length and the treatment outcome by PAI scores. Treatment information was achieved from the county's electronic dental record system. Information regarding the dental practitioners' background and treatment procedure routines was collected by a questionnaire. Descriptive statistics analyses and mixed-effect logistic regression analyses were performed to evaluate the effect of the course.

Results: Radiographs were available for 224 teeth root filled before and for 221 teeth after the course. The proportion of teeth with adequate root filling quality was significantly lower after the course ($p = .006$), associated mainly with short root fillings ($p < .001$). No significant differences were observed in treatment outcome. There were, however, large differences in treatment outcome amongst subgroups of dentists. Further, there was evidence of effect modification by the continuing education course on periapical outcome by patient's age ($p_{\text{interaction}} = .0023$) suggesting that teeth in patients ≤18 years healed relatively better post-course compared to patients >18 years.

Conclusions: A two-day continuing education course in root canal treatment attended by Public Dental Service dentists in Norway did not improve the technical quality of root fillings or periapical status associated with root filled teeth.

KEYWORDS

apical periodontitis, continuing education, endodontics, general dental practitioner, reciprocating technique, root filling quality

INTRODUCTION

Root canal treatment performed at dental educational institutions or in specialist practice has a success rate of 75%–85% in teeth with apical periodontitis and regularly more than 90% in teeth without pre-operative apical lesions (Llena et al., 2020; Ng et al., 2011; Ricucci et al., 2011; Sjögren et al., 1990). However, epidemiological studies of endodontically treated teeth show that up to 50% are associated with apical pathosis, detected by conventional periapical radiography (Fransson et al., 2016; Kirkevang et al., 2000; Koch et al., 2015; Meirinhos et al., 2020; Ridell et al., 2006; Skudutyte-Rysstad & Eriksen, 2006). Data from Norway have shown a prevalence of apical periodontitis in root filled teeth of 25% amongst children and adolescents and 43% amongst 35-year-olds (Jordal et al., 2014; Skudutyte-Rysstad & Eriksen, 2006).

The technical quality of root fillings has been stated to influence the outcome of root canal treatment (Bołtacz-Rzepkowska & Pawlicka, 2003; Boucher et al., 2002; Dugas et al., 2003; Eriksen et al., 2002; Kirkevang & Hørsted-Bindslev, 2002; Kirkevang et al., 2000, 2014; Lupi-Pegurier et al., 2002; Ng et al., 2011; Ricucci et al., 2011; Siqueira et al., 2005; Sjögren et al., 1990; Tsuneishi et al., 2005). Quality guidelines on root canal treatment procedures have been published by the European Society of Endodontology (ESE, 2006); however, several studies have revealed that root canal treatments in general dental practice are not always performed to the same standard as recommended by the guidelines (Dahlström et al., 2018; Kirkevang et al., 2014; Malmberg et al., 2020; Markvart et al., 2018; Neukermans et al., 2015; Peciuliene et al., 2009; Peters et al., 2011).

Whilst it may be possible to change and improve the clinical routines of dentists and the technical quality of the root fillings through pedagogical interventions (Dahlström et al., 2015; Koch et al., 2009; Molander et al., 2007; Reit et al., 2007), a corresponding improvement in the treatment outcome does not necessarily follow (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007). Studies on the effect of short endodontic hands-on courses on dentists in Norway have not been performed.

As part of a quality assurance programme in Endodontics, all dentists in the Public Dental Service (PDS) of Møre and Romsdal county in Norway were given a continuous education (CE) course designed to improve clinical understanding and procedures of root canal treatment. Findings from a recent questionnaire study indicated that the course had only a minor effect on participants' knowledge and insight in Endodontics (Jordal et al., 2021).

The objective of the present study was to investigate the effect of the CE course on the technical quality of root fillings and periapical status of root filled permanent teeth in Møre and Romsdal County, Norway. Also, the pooled data were used to analyse the performance of subgroups of the dentists regarding technical quality of root fillings and treatment outcome following root canal treatment.

MATERIAL AND METHODS

Study design

The project was presented to the Regional Ethics Committee (REC South-East Norway) without objections (ref no. 2015/265 B) and was approved by the Norwegian Center for Research Data, NSD (Ref no 39991). Because the attending dentists adopted a standard, nonexperimental treatment protocol, and because knowledge about health or disease *per se* is not the purpose of this study, this project falls outside the provisions of the Health Research Act, cf. section 4 and does not require local review board approval according to the European Guidelines for Good Clinical Practice (CPMP/ICH/135/95). The confidentiality and anonymity of patients and course participants were maintained in accordance with national and regional (Office of the Møre and Romsdal Public Dental Health Service) requirements. The manuscript was written in accordance with 'Strengthening the reporting of observational studies (STROBE)' recommendations (www.strobe-statement.org).

In 2015, all dentists of the PDS in the Norwegian County of Møre and Romsdal were invited to a CE course in root canal treatment, aiming to improve the technical quality and periapical outcome of root fillings. The course, consisting of two full-day sessions was implemented as compulsory post-graduate training (for details, see Jordal et al., 2021). Fifty-two of the 67 PDS employed dentists (78%) completed the course.

In short, the course comprised lectures with a comprehensive update on the aetiology and treatment principles of endodontic infections, including demonstrations and hands-on training with a reciprocating file system (RECIPROC VDW). The file system was presented in detail, and root canal preparation was demonstrated in

a video. The root filling technique in the course was a single cone supplemented, when necessary, with cold lateral condensation, demonstrated in a video and in one-to-one teaching sessions. Procedures were based on the ESE treatment guidelines (ESE, 2006). All dentists practised root canal instrumentation and filling in plastic molars ('Endo Training Tooth'; VDW). Practical training sessions were held under guidance by two experienced endodontists with academic as well as clinical background (DØ & KJ). The PDS provided the necessary equipment including engines and files ('Dentsply X-Smart Plus Wave One' engine with 'RECIPROC' files) to all clinics.

Inclusion criteria

Root filled teeth treated in PDS clinics before and after the course were identified from the county's electronic dental record system (EDR). Patients with at least one root canal treatment between 1 January 2014 and 31 December 2016, were identified via the EDR. Teeth were categorized into two groups based on whether they had been treated before or after the CE course. Inclusion criteria for evaluation of technical quality of root fillings and periapical outcomes were teeth treated by the 52 dentists who attended the course, and teeth with post-operative as well as follow-up radiographs of at least 1 year after treatment. Only one root filled tooth per patient was randomly selected for evaluation of periapical outcome. Radiographs had to be of adequate quality and include relevant anatomical structures.

Data collection

Information regarding the patients' gender and age, operator code, cases of retreatment and follow-up time was retrieved from the EDR system.

Information regarding the background characteristics of the dentists such as gender, place and year of education, as well as their endodontic treatment procedure routines, was retrieved from a questionnaire completed by the course participants (for details see (Jordal et al., 2021)).

Radiographic evaluation

All clinics used digital radiograph systems, either Digora phosphor storage plate (PSP) system (Soredex Orion Corp.) or Planmeca (Planmeca) intraoral sensor with Romexis (Planmeca) software.

The radiographs of root-filled teeth that met the inclusion criteria were coded and anonymously copied as TIFF files to a USB-flash drive. The radiographs were coded randomly to blind the examiner to whether the root filling had been performed before or after the course. The root filling quality was evaluated in follow-up radiographs by one examiner (KJ) using an extension of the image processing programme ImageJ (Rasband, 1997–2018, Schneider et al., 2012). The extension simplifies the measurements of endodontic parameters in periapical radiographs. For the evaluation of root curvature and length of the root filling, specific points are marked in the X-ray, and the application stores the coordinates to facilitate further calculations (Figure 1). Root filling density was recorded subjectively as either satisfactory (homogenous) or unsatisfactory (visible voids) (Figure 1). Overfilled root canals or fillings more than 2-mm short of root apex were considered of unsatisfactory length. Teeth with periapical extrusion of sealer were not considered as overfilled. Both density and length had to be satisfactory for the root filling to be considered of adequate quality. In cases of multirooted teeth, each root was assessed separately, and the tooth was assigned the score of the worst root. The coordinates defining canal entry, canal deviation, and root apex were used to calculate the root angle (a modified Schneider angle) in the same root (Schneider, 1971), which were labelled S angles and categorized into <25 and ≥ 25 degrees for no or slight versus marked curvature, respectively.

Periapical status was evaluated using the Periapical Index (PAI) (Ørstavik, 1996; Ørstavik et al., 1986) by two examiners (PTS and KJ). They were calibrated against 100 reference radiographs until an observer/reference agreement with a kappa value >0.61 was reached. The weighted kappa value for interobserver agreement of PAI scores was 0.86. After calibration, the two operators independently examined and PAI scored all radiographs. In cases of one PAI score value in difference, the higher score was chosen. The two observers agreed in 70% of all observations and in 98% whether the tooth was healthy (defined as PAI score 1 or 2) or not. In 14 of 251 cases of disagreement, the difference was of two or more PAI score values. These images were reviewed again, and a final consensus was reached after discussion with a third evaluator (DØ). Similar to the procedure for technical quality, in multirooted teeth, the root with the poorest status (highest PAI score) was selected for analyses.

When one patient had more than one tooth treated endodontically during the study period, one tooth per patient was randomly selected for evaluation of periapical status.

The outcome statistics used in calculations were

1. Technical quality: 'adequate' defined as root fillings without visible voids, ending ≤ 2 mm from the radiographic apex;

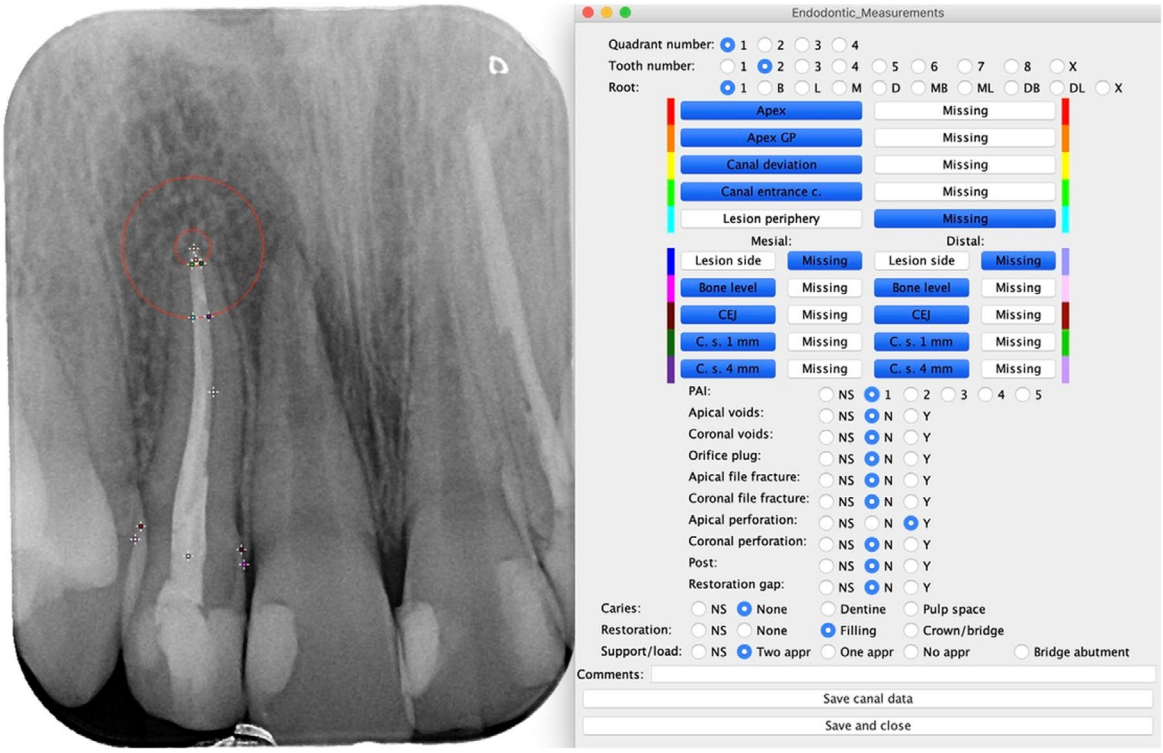

FIGURE 1 Screenshot of the ImageJ application interface

2. Periapical outcome: 'healthy' defined as all teeth with PAI 1 or 2 at follow-up (strict criterium); and
3. Periapical outcome: 'healing' defined as all teeth with PAI 1 or 2 at follow-up plus teeth with PAI 4 or 5 at start, which scored PAI 3 at follow-up (less strict criterium).

Statistical analyses

Descriptive statistics of the variables were presented as frequencies and percentages. Inter-group comparisons between categorical variables were assessed using Pearson's chi-squared test. Teeth-treated pre- and post-course were compared with regard to patient age (below or above 45 years), gender, tooth type (molars versus incisors/pre-molars), root canal curvature (S angle), pre-operative periapical diagnosis (apical periodontitis versus healthy), retreatments, visible rubber-dam clamp in radiographs, and follow-up period (up to 2 years versus longer) as well as distribution of teeth according to PAI score. Furthermore, the quality of root filling (0 = not adequate, 1 = adequate) and periapical outcome (0 = not healthy, 1 = healthy) in teeth-treated pre- and post-course were assessed in relation to background characteristics of the dentists. The effect of the CE course on the technical quality of root filling (0 = not adequate, 1 = adequate), and on the probability of successful endodontic treatment outcome (0 = not healthy, 1 = healthy) was assessed. Due to the clustered structure of the data, mixed-effect logistic regression analyses with robust variance estimator were performed. Two-level analyses were carried out, with teeth at level 1 and dentists at level 2. The same set of exposures were used in the multivariable analyses. For regression analyses, only dentists who treated teeth both before and after the CE course were included. Two models were constructed. Model 1 was unadjusted, and Model 2 was adjusted for dentist gender (male/female), place of education (in Norway, abroad), and dentist's experience (<12 years vs. ≥12 years). In addition, sensitivity analyses were performed using a less strict definition for periapical health status (healing), where Healing = any PAI1 or 2 at follow-up plus any PAI 4 or 5 at start scored as PAI 3 at control.

In secondary analyses, the effect modification was assessed by tooth type (molars vs. nonmolars), root curvature by the S angle (≥25 vs. <25), patient age (<18 years vs. ≥18 years), dentist's experience (<12 years vs. ≥12 years), patient's follow-up time (up to 2 years vs. ≥2 years of follow-up), and technical quality of the root filling on successful endodontic treatment outcome. The relevant multiplicative interaction parameter was included in the models and assessed for statistical significance by likelihood ratio test.

Statistical analyses were performed using SPSS 26 version (SPSS Inc.; IBM) and the significance level was set at

$p < .05$. The mixed-effect logistic regression analyses were conducted using Stata version 15 (Stata Corp).

RESULTS

Five hundred one teeth were treated in the period from January 2014 until course-day 1 in October 2014 (pre-course) and 544 teeth in the period after course-day 2, from October 2015 to end of December 2016 (post-course). Post-operative and follow-up periapical radiographs were available for 224 of 501 teeth (45%) pre-course and 221 of 544 (41%) post-course. For evaluation of technical quality, 224 teeth pre-course and 221 teeth post-course were analysed. For evaluation of periapical outcome, one tooth per patient was randomly selected, excluding 17 teeth pre-course and 16 teeth post-course (see flow chart Figure 2). Participating dentists contributed with different number of teeth, both in total and in the proportion pre- and post-course (Table S1). Thirty-nine dentists contributed with teeth to the pre-course period and 48 dentists contributed to the post-course period. Thirty-five dentists contributed to both periods. The follow-up time ranged from 12 to 60 months. The pre-course treated teeth had relatively longer follow-up time than the post-course treated teeth, (60% vs. 37% >2 years) and more molar teeth were treated post-course (31% vs. 40%). No significant differences in the proportions of teeth with 'pre-operative apical periodontitis', 'retreatments', 'marked root curvature' and 'visible rubber-dam clamp on radiograph' were observed in the pre- and the post-course groups (Table 1).

Course effects on technical quality and treatment outcome

The distribution of teeth-treated pre- and post-course in relation to root filling quality is presented in Table 2. The proportion of teeth with adequate root filling quality (density + length) decreased significantly from 48% pre-course to 35% post-course ($p = .006$). The proportion of teeth with adequate root filling length *per se* were reduced significantly from 59% to 47%, mainly because short root fillings increased from 24% to 40% ($p < .001$).

For the entire material, no significant difference in outcome pre- and post-course was found either by strict criteria or by the less strict definition of healing as shown in Table 2. For teeth with pre-operative apical periodontitis, however, there was a significant reduction in the proportion of root filled teeth scored as 'healthy' after the course (56% vs. 39%, $p = .016$).

The distribution of teeth in relation to post-operative changes in PAI scores at follow-up is presented in Table 3. Although the proportions are fairly similar pre- and post-course, more of the definite lesions (PAI 4 + 5) did not heal (PAI1 + 2) post-course.

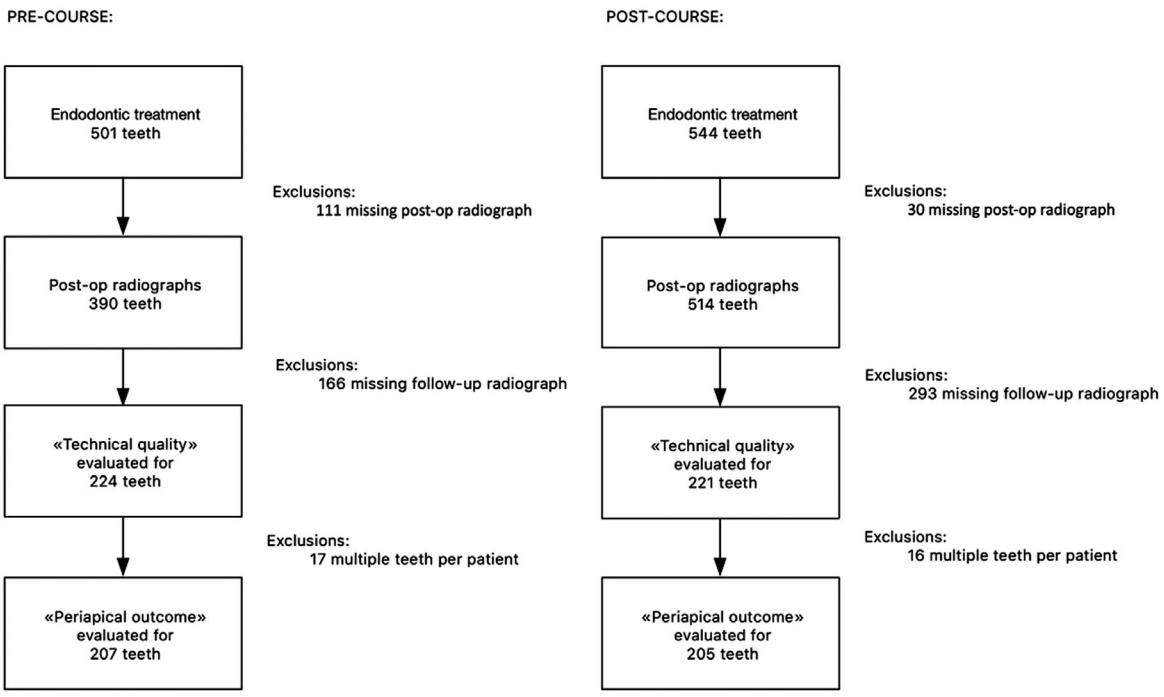

FIGURE 2 Flow chart of teeth-treated pre- and post-course

TABLE 1 Distributions of root filled teeth evaluated for periapical outcome

	Pre-course ($n = 207$) n (%)	Post-course ($n = 205$) n (%)	p-Value[a]
Molars	64 (31)	81 (40)	.079
Pre-operative apical periodontitis (PAI 3+4+5)	94 (45)	95 (46)	.921
Definite pre-operative apical periodontitis (PAI 4+5)	42 (20)	61 (30)	**.031**
Retreatments	13 (6)	9 (4)	.512
S angle ≥25	39 (19)	43 (21)	.623
Rubber-dam clamp on radiograph	104 (50)	108 (53)	.624
Follow-up >2 years	**124 (60)**	**75 (37)**	**<.001**

Note: Results significant at 5% level marked in bold.

Abbreviations: PAI, periapical index; S angle, Schneider angle, measure of root curvature.

[a]Chi-squared test.

TABLE 2 Distributions of teeth-treated pre- and post-course in relation to technical quality and periapical outcome

	Pre-course n (%)	Post-course n (%)	p-Value
Technical quality	($n = 224$)	($n = 221$)	
Adequate	**108 (48)**	**78 (35)**	**.006**
Satisfactory density	156 (70)	144 (65)	.313
Satisfactory length	**132 (59)**	**103 (47)**	**.003**
Too short	**53 (24)**	**89 (40)**	**<.001**
Too long	39 (17)	29 (13)	.418
Periapical outcome at follow-up	($n = 207$)	($n = 205$)	
Healthy	146 (71)	127 (62)	.066
Healing	158 (76)	150 (73)	.461
PAI 1 + 2 at start	($n = 113$)	($n = 110$)	
Healthy	93 (82)	90 (82)	.925
PAI 3 + 4 + 5 at start	($n = 94$)	($n = 95$)	
Healthy	**53 (56)**	**37 (39)**	**.016**
Healing	65 (69)	60 (63)	.384

Note: 445 teeth (224 pre-course + 221 post-course) included for evaluation of technical quality. 412 teeth (207 pre-course + 205 post-course) included for evaluation of periapical outcome. Results significant at 5% level marked in bold. Adequate quality: satisfactory length and density; Healthy: PAI 1 or 2 at follow-up; Healing: PAI 1 or 2 at follow-up plus PAI 4 or 5 at start scored as PAI 3 at follow-up.

Other factors associated with technical quality and treatment outcome

For assessment of factors associated with technical quality and periapical outcome, 16 and 15 teeth, respectively, were excluded due to the nonresponse of 3 dentists to the background questionnaire (Table 4). Analyses of all root filled teeth (pre- and post-course) in relation to background characteristics of dentists indicated that teeth treated by female dentists had more often adequate root filling quality and good periapical health at follow-up (Table 4), and teeth treated by dentists educated in Norway and dentist who claimed to always use rubber dam were more often scored as healthy at follow-up.

Mixed-effect logistic regression analyses

The mixed-effect logistic regression analysis of teeth-treated pre- and post-course with root filling quality and periapical outcome as dependent variables is presented in Table 5. Only teeth treated by the 35 dentists who contributed to both periods were included to avoid data clustering on dentist level. In the unadjusted model, the course had a significant inverse association with the overall technical quality and the periapical outcome of the root canal treatment. The results on technical quality remained significant after adjusting for dentists' gender, years of experience and education place, but there was no significant effect of the course on periapical health in the adjusted model. Further, the sensitivity analyses using less strict definition for periapical outcome revealed that the results did not vary from the main analyses.

When assessing effect modification on the outcome variables (root filling quality and periapical outcome) by selected modifiers presented in Table 6, the p-value for interaction on 'patient age ≤18' was significant ($p_{\text{interaction}} = .0023$) and indicated that this group healed relatively better post-course compared to the peer group (>18 years).

TABLE 3 Distribution of teeth according to PAI score between teeth-treated pre- and post-course

	Follow-up PAI 1 + 2	Follow-up PAI 3	Follow-up PAI 4 + 5	Total
	n (%)	*n* (%)	*n* (%)	*n*
Pre-course				
Start PAI 1 + 2	93 (82)	12 (11)	8 (7)	113
Start PAI 3	31 (60)	11 (21)	10 (19)	52
Start PAI 4 + 5	22 (52)	12 (29)	8 (19)	42
Post-course				
Start PAI 1 + 2	90 (82)	15 (14)	5 (5)	110
Start PAI 3	21 (62)	6 (18)	7 (21)	34
Start PAI 4 + 5	16 (26)	23 (38)	22 (36)	61

Abbreviation: PAI, periapical index.

TABLE 4 Technical quality and periapical outcome of root-filled teeth related to background characteristics of dentists

	Technical quality			Periapical outcome		
	Adequate	Inadequate		PAI1 + 2	PAI3 + 4 + 5	
	n (%)	*n* (%)	*p*-Value	*n* (%)	*n* (%)	*p*-Value
Dentist's gender						
Female	130 (48)	146 (52)	**.004**	191 (74)	67 (26)	**<.001**
Male	56 (33)	113 (67)		82 (53)	72 (47)	
Educated in Norway						
Yes	120 (43)	156 (57)	.415[a]	178 (70)	76 (30)	**.027**[b]
No	60 (40)	93 (60)		84 (59)	59 (41)	
Always use rubber dam						
Yes	44 (41)	63 (59)	.910[a]	74 (76)	23 (24)	**.019**[b]
No	136 (42)	186 (58)		188 (63)	112 (37)	
Dentist experience <12 years						
Yes	70 (48)	75 (52)	.063[a]	92 (69)	42 (31)	.436[b]
No	110 (39)	174 (61)		170 (65)	93 (35)	

Note: 445 teeth (224 pre-course + 221 post-course) included for evaluation of technical quality. 412 teeth (207 pre-course + 205 post-course) included for evaluation of periapical outcome. The analysis was performed by Pearson's chi-squared test. Results significant at 5% level marked in bold. Adequate quality: satisfactory length and density.

[a]16 teeth were excluded due to 3 dentists' nonresponse of the questionnaire.

[b]15 teeth were excluded due to 3 dentists' nonresponse of the questionnaire.

DISCUSSION

The PDS in Møre and Romsdal is responsible for dental care of children and adolescents 0–20 years, the intellectually disabled, elderly and physically disabled in institutions or granted home nursing, and other groups that the county municipality has decided to prioritize. The PDS has a uniform digital patient record system, and this made it feasible to collect information from a large number of dental records. The background characteristics of course participants appeared to be similar to those of practitioners in the PDS in other parts of Norway (Bletsa et al., 2019; Uhlen et al., 2019) and thus potentially represent a wider population of dental providers in PDS.

Scoring of root filling quality was performed in the ImageJ extension. As the anatomical areas were described and no interpretation was required, calibration or use of two examiners was not considered necessary. Root fillings were categorized as 'adequate' or 'inadequate' with regard to length and density. Root fillings ending ≤2 mm from radiographic apex were considered of adequate length, as in the study by (Koch et al., 2015), but slightly different from (Molander et al., 2007) and (Dahlström et al., 2015) who used a limit of ≤2.5 mm, and from (Kirkevang et al., 2000) who used ≤3 mm from

TABLE 5 Mixed-effect logistic regression analyses to assess the association of CE course on technical quality and periapical outcome

	Model 1			Model 2		
	OR	**95% CI**	***p*-Value**	**aOR**	**95% CI**	***p*-Value**
Adequate quality[a]						
Pre-course (reference)	1.00		**<.001**	1.00		**<.001**
Post-course	0.51	(0.35–0.73)		0.52	(0.36–0.75)	
Level 1: teeth		$n = 374$			$n = 362$	
Level 2: dentists		$n = 35$			$n = 33$	
Periapical outcome: healthy[b]						
Pre-course (reference)	1.00		**.037**	1.00		.082
Post-course	0.60	(0.37–0.97)		0.67	(0.43–1.05)	
Level 1: teeth		$n = 347$			$n = 336$	
Level 2: dentists		$n = 35$			$n = 33$	

Note: Model 1 is unadjusted, and Model 2 adjusted for dentists' gender, dentists' years of experience and dentists' place of education. Results' significant at 5% level marked in bold; Adequate quality: satisfactory length and density; Periapical outcome: healthy: PAI 1 + 2 at follow-up.

Abbreviations: aOR, adjusted Odds ratio; CI, confidence interval; OR, Odds ratio.

[a]Missing values: 71 teeth treated by dentists only producing root fillings either before or after CE course were excluded. *N* in Model 2 is further reduced as 12 teeth were excluded due to 2 dentists' nonresponse to dentists' years of experience or dentists' place of education in the questionnaire.

[b]Missing values: 65 teeth treated by dentists only producing root fillings before or after CE course were excluded. *N* in Model 2 is further reduced as 11 teeth were excluded due to 2 dentists' nonresponse to dentists' years of experience or dentists' place of education in the questionnaire.

the radiographic apex. As there were no aim to set a standard for adequate root fillings, but rather compare two groups of teeth, ≤2 mm was optimal for statistical calculations with the data.

For each of the included teeth, periapical status was assessed using the PAI index. The index is well established in endodontic epidemiology and follow-up studies and provides reproducible assessment of periapical status. The interobserver agreement on PAI scores was high, thus the scores should be deemed reliable.

Randomly including one tooth per patient to study periapical outcome was done to ensure the independence of the data and to avoid data clustering. The individual dentist´s contribution of root-filled teeth was unevenly distributed and could have been a possible source of bias. Therefore, cases from dentists who did not perform root canal treatments both before and after the course were excluded. Due to some dentists' lack of routines of taking post-operative or follow-up radiographs, only 45% of the root filled teeth in the pre-course group and 41% in the post-course group were included in the final analyses. The large drop-out rate may limit the validity of the outcomes.

The findings of the present study indicate that no improvements in the technical quality of root fillings occurred after the course. On the contrary, a decrease in a proportion of adequate root fillings was found, particularly regarding root filling length. One feasible explanation for this could be that one focus in the educational course was that extruded root fillings negatively affect treatment outcome in infected teeth, which may have resulted in dentists trying to avoid producing long root fillings after the course and instead making them too short.

The increase in the proportion of inadequate root fillings post-course is in contrast to similar studies showing improvement in technical quality after introduction of rotary files (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007). In some of these studies a different method for quality scores was used, which in addition to measuring length and density included taper and transportation (Dahlström et al., 2015; Molander et al., 2007). Rotary techniques provide greater taper and less transportation than conventional techniques (Del Fabbro et al., 2018; Taşdemir et al., 2005), which may improve that aspect of the score for optimal technical quality.

The present study and similar studies performed in Sweden (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007) are based on teeth treated by dentists working in the PDS. However, the PDS in Sweden (Folktandvården) has a slightly different patient profile compared to the Norwegian PDS. In addition to the priority groups, Swedish PDS treat almost half of all adults (https://folktandvarden.se). The present material consisted of 31% molars pre-course and 40% post-course. (Koch et al., 2015) did not describe the proportions of molars in their study while (Molander et al., 2007) and (Dahlström et al., 2015) studied exclusively molars. In the Swedish studies (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007), the predominant pre-course technique was conventional hand file canal instrumentation (79%–96%) compared to only 62% in the present material. Therefore, the dentists in Møre and Romsdal may

TABLE 6 Impact of possible effect modifiers on technical quality and periapical outcome – a mixed-effect logistic regression analysis

	n pre	*n* post	aOR	95% CI	*p*-Value of interaction
Adequate quality[1]					
Molars	60	59	0.46	(0.21–1.01)	.57
Nonmolars	136	107	0.63	(0.40–0.98)	
S angle ≥25	40	35	0.36	(0.13–1.01)	.59
S angle <25	156	131	0.57	(0.39–0.84)	
Patient age >18	157	123	0.54	(0.36–0.80)	.82
Patient age ≤18	39	43	0.45	(0.16–1.32)	
Dentist experience ≥12 years	133	100	0.66	(0.39–1.09)	.17
Dentist experience <12 years	63	66	0.36	(0.21–0.63)	
Periapical outcome: healthy[2]					
Molars	57	57	0.79	(0.40–1.57)	.82
Nonmolars	126	96	0.71	(0.38–1.32)	
1–2 years follow-up	72	91	0.81	(0.41–1.60)	.33
>2 years follow-up	111	62	0.49	(0.25–0.95)	
Adequate quality	101	80	0.54	(0.28–1.02)	.43
Inadequate quality	82	73	0.86	(0.47–1.57)	
Patient age >18	141	112	0.45	(0.29–0.68)	**.0023**
Patient age ≤18	42	41	2.85	(0.75–10.81)	
Dentist experience ≥12 years	120	97	0.55	(0.32–0.96)	.28
Dentist experience <12 years	63	56	0.91	(0.40–2.09)	

Note: Exposure was pre/post-CE course (pre as reference). Adjusted for dentists' gender, dentists' years of experience and dentists' education in Norway. Missing values: on technical quality and periapical outcome, 71 and 65 teeth, respectively, were treated by dentists only producing root fillings before or after courses and 12 and 11 teeth due to 2 dentists' nonresponse of the questionnaire, were excluded. Adequate quality: satisfactory length and density; Periapical outcome: healthy: PAI 1 + 2 at follow-up. Effect modifiers marked in bold.

Abbreviations: aOR, adjusted Odds ratio; CI, confidence interval; *n* post, number, post-course; *n* pre, number, pre-course.

have started at a baseline with potentially better technical quality than their Swedish counterparts.

No significant change in the overall periapical status was found after the course and this finding is in accordance with previous studies. Despite improved technical quality of root fillings, (Koch et al., 2015) also did not show improved treatment outcome. However, when teeth with pre-operative apical periodontitis were analysed separately, there was a decrease in teeth scored as healthy at follow-up after the course. Short and overextended root fillings are associated with significantly lower success rates (Ng et al., 2011; Sjögren et al., 1990); therefore, the lack of improvement in outcome post-course in this study could be due to the increased proportion of short root fillings.

It is also conceivable that the dentists decided to treat more difficult teeth after the course. These may be associated with a poorer prognosis and thus influence the outcome. Pre-operative apical periodontitis, molars, and retreatments are considered to influence the outcome (Frisk et al., 2008; Kirkevang & Hørsted-Bindslev, 2002; Kirkevang et al., 2007; Ng et al., 2008; Torabinejad et al., 2009). There was higher proportion of teeth with pre-operative definite apical periodontitis (PAI 4 + 5) post-course (Table 1). There was a tendency of higher number of molar teeth-treated post-course; however, the difference did not reach statistical significance. This indicates that there were only minor differences in treatment difficulty after the course. Retreatments may be associated with poorer prognosis, but the proportion of retreatments was low and similar for both the pre- and post-course group. The proportion was also similar to those reported in a study based on GDPs working in the PDS in Sweden (Wigsten et al., 2019).

There were significantly longer follow-up times for teeth in the pre-course group, with an average of 30 months, in contrast to 21 months post-course. Some teeth need more time to heal, thus a better outcome could be expected with longer follow-up (Ng et al., 2007; Ørstavik, 1996). However, the multivariate analysis of outcome in the data revealed that the length of follow-up had no significant impact on healing. Although the importance of follow-up radiographs was emphasized repeatedly during the course, less than half of the root canal treatments included a follow-up radiograph, before and after the course.

The background questionnaire revealed that several generally accepted procedures in clinical root canal treatment were not routinely applied by a large proportion of the dentists (Jordal et al., 2021). Twenty two per cent reported not always taking post-operative radiographs and only 37% reported always using rubber dam. Information from the questionnaire on gender, place of education and years of experience, made it possible to assess differences in technical quality and outcome of root canal treatment between subgroups of practitioners. Root canals treated by female dentists had a better outcome in both root filling quality and periapical health. A better periapical outcome was observed for teeth treated by dentists educated in Norway versus abroad, whilst years of experience did not seem to have much impact. Lack of rubber-dam use has been associated with significant reduced survival rate of root filled teeth (Kwak et al., 2019; Lin et al., 2014). Teeth root filled by dentists claiming always to use rubber dam (Jordal et al., 2021) had better results in terms of healing (Table 4). However, the results are based on a small sample of dentists and conclusions should be drawn with caution.

There was evidence that the effect of CE course on root filling quality and periapical outcome was modified by patient's age ($p_{\text{interaction}} = .0023$) suggesting that the younger patients' teeth (≤18 years) healed relatively better post-course compared to the peer group (>18 years). Post-course, a larger proportion of the younger teeth were treated by dentists with <12 years' experience, dentists claiming to 'always use' rubber dam, and teeth with a visible rubber-dam clamp on working length radiographs (data are not shown). Usage of rubber dam did indeed have a positive impact on periapical outcome (Table 4).

The finding that a two-day education course in root canal treatment did not have positive impact on treatment outcome is not unique. A Cochrane study from 2009 based on 30 randomized controlled trials (RCTs) concluded that educational meetings on professional practice and health care did not appear to be effective for complex behaviours (Forsetlund et al., 2009). The behaviour was categorized as complex when a number of behaviours were required, or complex judgements or skills were necessary. Root canal treatment is considered a complex and particularly technically demanding field of dentistry and thus could be categorized as such.

A high prevalence of apical periodontitis in root filled teeth reported in epidemiological studies suggests that there is a need for quality improvement for root canal treatments performed in general practice. However, it is a complex educational problem to improve treatment quality and outcomes. Dentists may not change established clinical routines easily. Efforts were made to prepare and plan a CE course to be of the best possible benefit to the participants (Jordal et al., 2021). Most dentists participating in the course (78%) reported that they performed root canal treatment less than once in a regular week (Jordal et al., 2021). The lack of reinforcement by root canal treatment in daily practice could be one possible explanation for the lack of improvement in quality and outcome. It is also possible that a two-day course may be too limited to effectively change clinical routines incorporated through a professional career. It might also be that a closer follow-up of the participants in between the course sessions, for example with clinic visits by the course holders, would have increased the effect of the course. However, with many clinics involved, this approach was considered too resource intensive.

CONCLUSION

A two-day continuing education course in root canal treatment for the dentists in PDS in Norway did not improve the technical quality of root fillings or outcome of root canal treatments. Findings from the present study suggest that postgraduate training of dentists is challenging, and more knowledge is needed on implementation of new knowledge and means of changing established daily procedures amongst dentists.

CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interests in connection with this article.

AUTHORS CONTRIBUTION

Kristin Jordal - main author, the conception and design of the study, drafting the article, acquisition of data and interpretation of data. Rasa Skudutyte-Rysstad - epidemiology, the conception and design of the study, analysis and interpretation of data, revising the article critically, final approval of the version to be submitted. Abhijit Sen - statistics, analysis and interpretation of data, revising the article critically, final approval of the version to be submitted. Gerald Torgersen - digital tools, analysis and interpretation of data, revising the article critically, final approval

of the version to be submitted. Dag Ørstavik - experience and overview, drafting the article, the conception and design of the study, analysis and interpretation of data, revising the article critically, final approval of the version to be submitted. Pia Titterud Sunde - close follow-up and main responsibility, drafting the article, the conception and design of the study, interpretation of data, revising the article critically, final approval of the version to be submitted.

ORCID

Kristin Jordal https://orcid.org/0000-0002-8340-2544

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